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THE UNIVERSITY OF ALBERTA

MID-DEVONIAN ELK POINT GROUP AND CAMBRIAN ROCKS
OF NORTH-CENTRAL ALBERTA

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

by

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EDMONTON, ALBERTA

APRIL, 1963

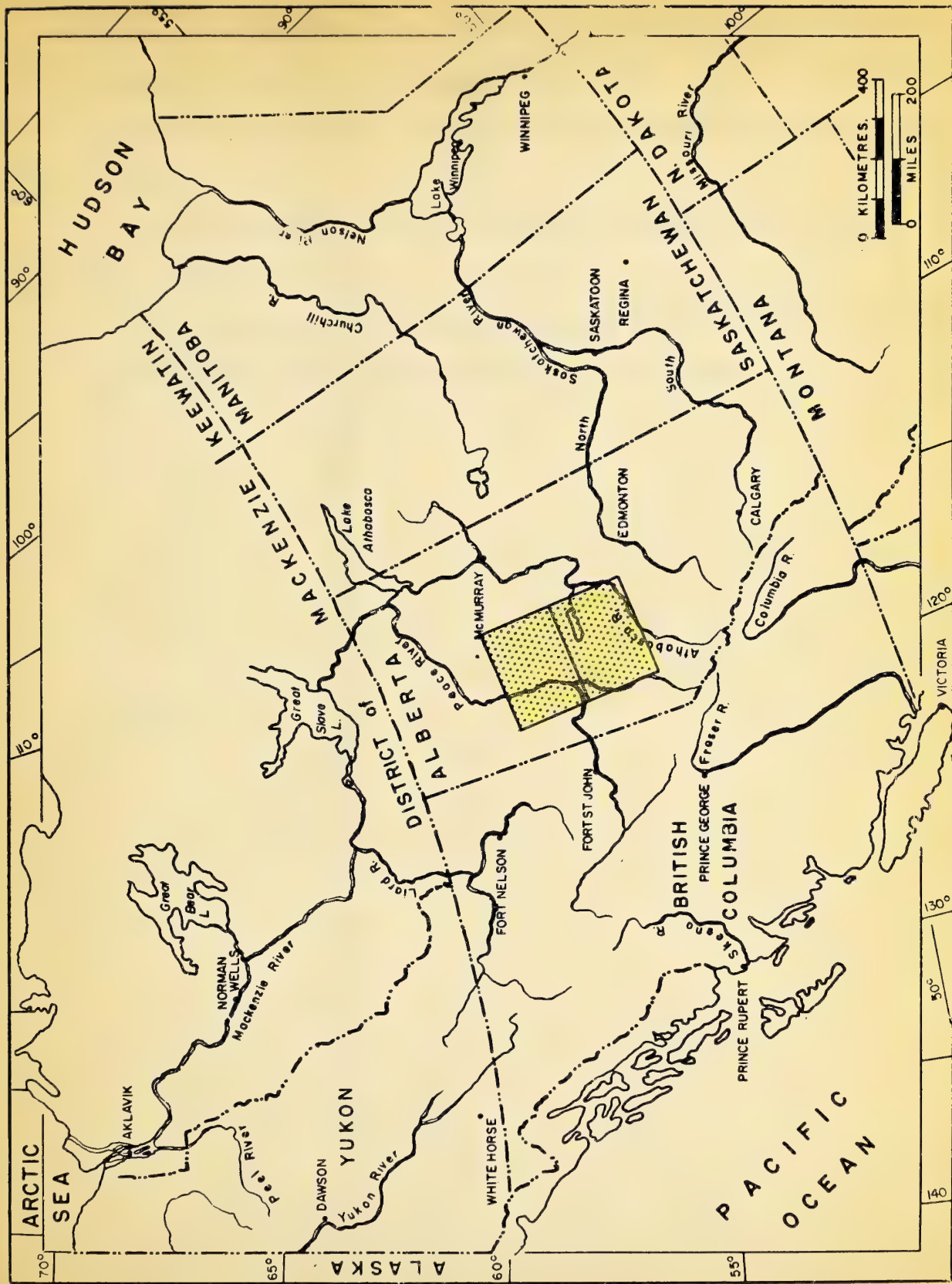
ABSTRACT

North-central Alberta is a part of the Interior Plains of Western Canada, contains 1,550 square miles and is underlain by an average thickness of 7,500 feet of Paleozoic and Mesozoic sediments. Lower Cambrian, Ordovician, Silurian and Lower Devonian beds are absent.

Middle and Upper Cambrian beds are subdivided into eight lithologic units, and contain mainly epineritic stable shelf sandstones and carbonates which appear to be indicative of proximity to the Cambrian shorelines. The Cambrian strata have a maximum thickness of 1200 feet in the south and are truncated progressively northward by the pre-Devonian unconformity.

In contrast to the surface of the Precambrian unconformity, the surface of the pre-Devonian unconformity appears to have considerable relief.

The Middle Devonian Elk Point Group is subdivided into a Red Bed Unit, a Clastic and Evaporitic Unit and the Watt Mountain Formation. These units onlap westerly, are absent in the western part of the map area, and attain a thickness of 1,100 feet in the east. The depositional environment of the Elk Point Group apparently differed in the north and in the south: in the north the evaporitic facies pinch out abruptly against the land mass; in the south a broad westward facies change and thinning is indicated. Two feldspathic sandstone members of the Elk Point Group spread into the southern map area. The lower, ^{the} proposed Assineau Sandstone of this paper, forms a wedge up to 200 feet thick at the diachronic base of the Clastic and Evaporitic Unit. The upper, ^{the} Gilwood Sandstone, forms a sheet up to 60 feet thick and is developed within the Watt Mountain Formation. The sands appear to indicate transgressive periods of the Elk Point Group and both "shale-out" easterly.



INDEX MAP : NORTH-CENTRAL ALBERTA
AS USED IN THESIS

The Elk Point sequence of the area discussed provides a continuous lithological correlation between the Elk Point section of central Alberta, described by Crickmay (1954) and that of northwestern Alberta, described by Law (1955).

The regional structure in north-central Alberta is homoclinal with gentle dips to the southwest.

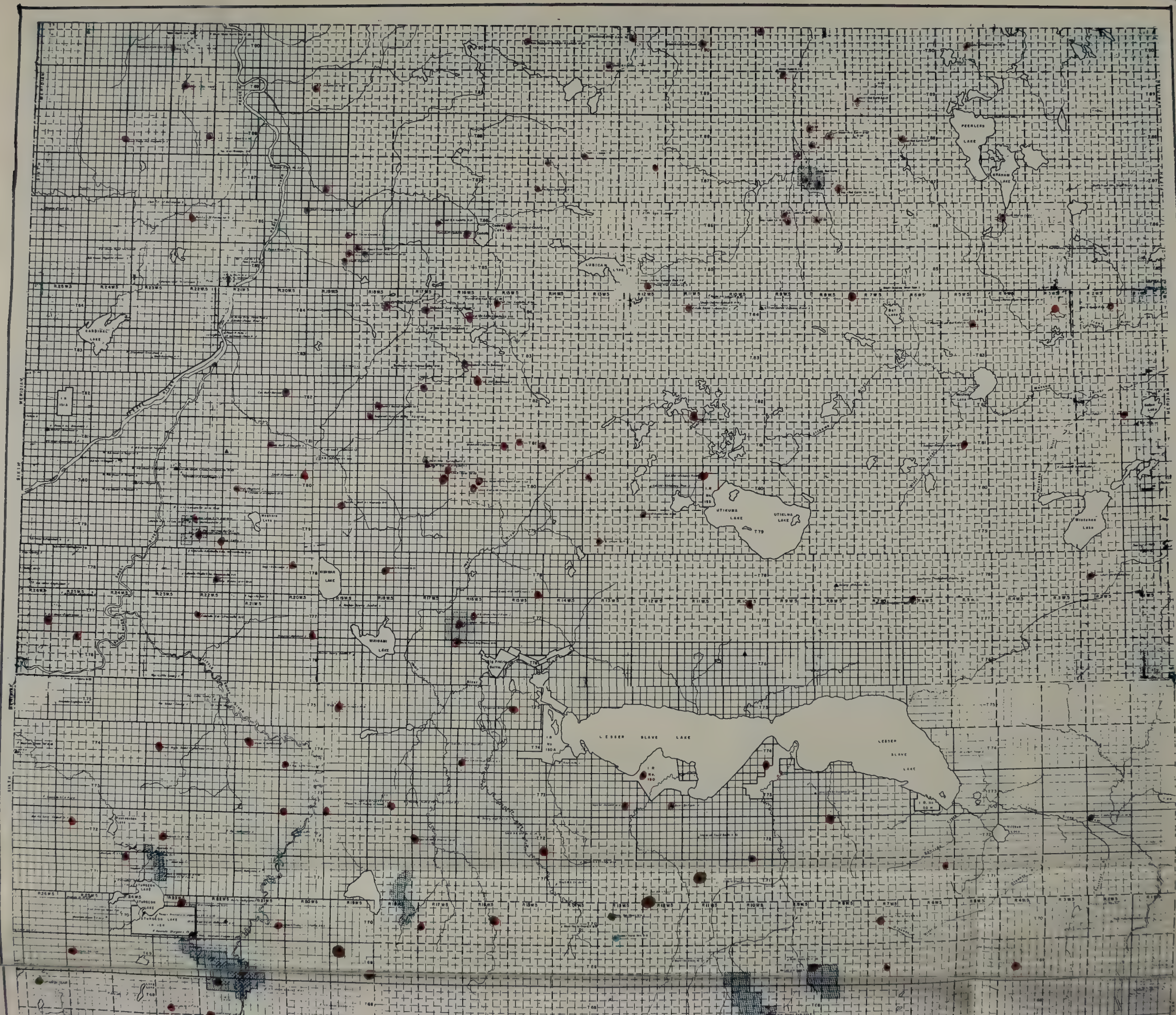
Several prospective hydrocarbon reservoir beds are present in Cambrian sediments and in the Devonian Elk Point beds of the map area.

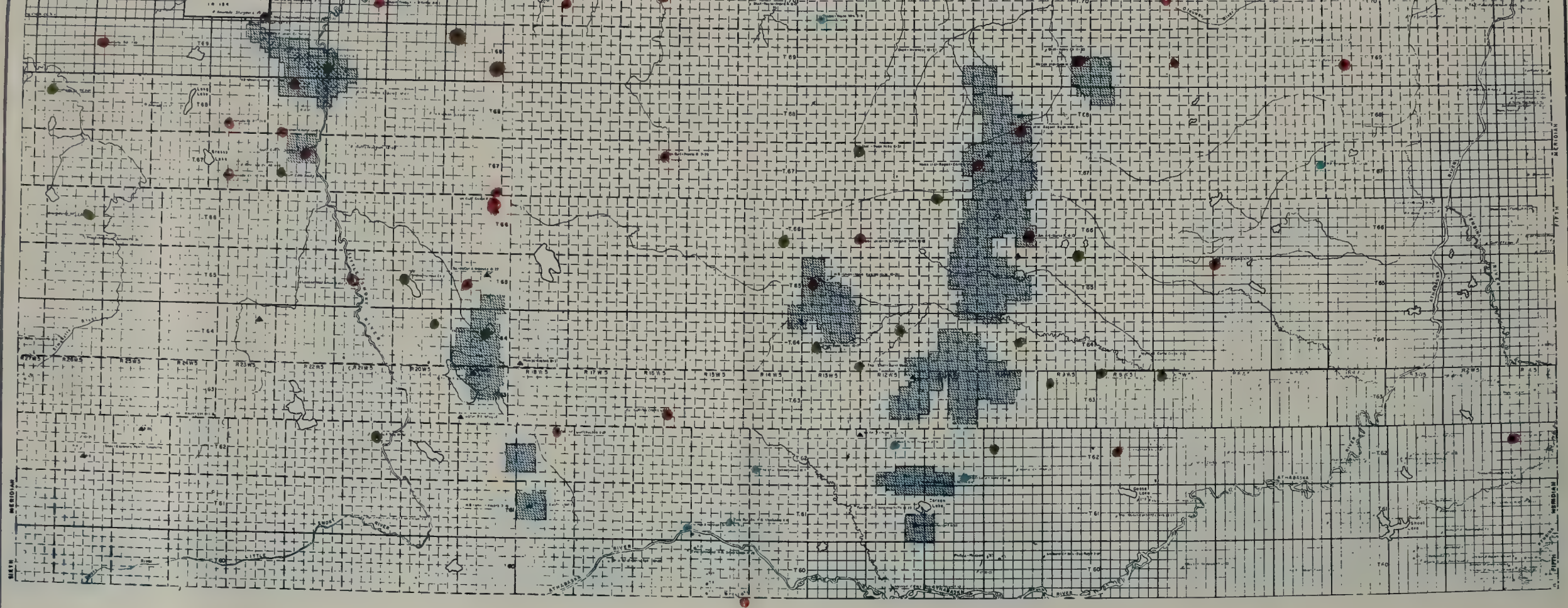
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Miss Sheila Baker typed the thesis and Mr. F. Dimitrov prepared certain illustrations.





EXPLORATION MAP

MAP 1

Showing rocks penetrated at control wells

NORTH-CENTRAL ALBERTA

Scale: 1" = 12 miles

LEGEND



Major oil and/or gas fields

Deepest rocks penetrated at control wells:

- Devonian Elk Point Group
- Cambrian
- Precambrian or Granite Wash

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INTRODUCTION

The area of north-central Alberta is a part of ^{the} Interior Plains of Canada. As defined in this paper it lies between townships 60 and 90 and between the 5th and 6th meridians, and contains 1550 square miles.

The geology described is based entirely on data available from deep wells drilled prior to the summer of 1962, some of which did not penetrate the entire section. Well cuttings of the interval between the Upper Devonian Woodbend Formation and the Precambrian from 120 wells were examined with the binocular microscope (cf. the Appendix), Electric and/or radioactive logs and drill-stem test and production data of these and an additional 150 wells were studied.

This paper describes the geology of the Middle Devonian, Elk Point Group and older sediments. It contains results of a part of a more extensive study of Upper Devonian and older rocks conducted by the writer in Northern Alberta, i.e., in the area contained between the 5th and 6th meridians and between township 60 and the boundary of the Northwest Territories. The general aspects of this thesis were briefly dealt with by the writer in a talk given at the 1960 symposium of American Association of Petroleum Geologists (unpublished), at Jasper.

PREVIOUS WORK

Cambrian

To date, no detailed papers dealing with the Cambrian geology of the map area have been published. Crickmay has identified Middle and Upper Cambrian fauna from the cores of Fina Stanolind Windfall No. 12-36 (tp. 59, rge. 15, W. 5th mer.) and Fina Stanolind Sundance No. 15-29 (tp. 55, rge. 17, W. 5th mer.) located one and 25 miles south of the map boundaries, respectively (personal communication prior

to 1957, later mentioned by Belyea, 1959). The present writer described and subdivided the Cambrian sequence of the map area into eight lithological units in 1957 and later described them in more detail in 1959 (unpublished reports).

Regional stratigraphic papers which include the Cambrian sediments of the map area are those by Webb (1951), de Mille (1958), Warren and Stelck (1958), Sikabonyi (1959) and van Hees (1959).

The nearest Cambrian type section crops out 150 miles to the southwest of the map area at Mount Robson, and was described by Walcott in 1913 and subsequently by Burling (1923), Walcott (1928), Kindle (1929a), Raymond (1930a), Rasetti (1951); North and Henderson (1954); Mountjoy (1962). In a final summary by Burling (1955) the total Cambrian thickness there was given as over 9000 feet and consists of 2600 feet of Lower Cambrian, 2450 feet of Middle Cambrian and a minimum of 4225 feet of Upper Cambrian; whereas Mountjoy (1962) measured about 4500 feet of Lower Cambrian, 1000 to 1500 feet of Middle Cambrian, and 3000 to 3200 feet of Upper Cambrian (which might include some Middle Cambrian as well).

Several authors have described the Cambrian of the central and southern Alberta Rockies. A stratigraphic summary of the Cambrian in that area was given by North (1953). Hughes in 1953, North and Henderson in 1954 and Mountjoy in 1962 presented correlations of the Cambrian beds of the Rocky Mountains. The table below, based on their data, compares Middle and Upper Cambrian type sections in the Bow Valley and in the Mount Robson area.

STANDARD SECTION	BOW RIVER VALLEY	MOUNT ROBSON	FAUNAL ZONES
	C.D. Walcott (1928) F. Rasetti (1961)	L.D. Burling (1955)	
UPPER CAMBRIAN	Goodsir (lower) Sabine Sherbrooke Paget Bosworth Arctomys ? — Pika	Lynx Pika	<u>Housia</u> <u>Prosaugia-Ptychaspis</u> <u>Crepicephalus</u> <u>Cedaria</u>
MIDDLE CAMBRIAN	Eldon Stephen Cathedral Mount Whyte	Titkana Tatei Chetang Hota-Adolphus	<u>Thompsonaspis</u> <u>Glossopleura</u> <u>Albertella</u> <u>Plasiura-Kochaspis</u>

No detailed work has been published on the Cambrian sediments of the Alberta and Saskatchewan Plains to the southeast of the area discussed. Regional data were included in some of the stratigraphic summaries mentioned above and also in those by Borden (1955) and Gussow (1957). The area of Borden's discussion of the Alberta and Saskatchewan Plains extends as far north and west as the Dapp No. 1 and Mitsue No. 14-30 wells which are in the easternmost area of this paper. Borden illustrates a progressively northward erosion of the Cambrian, and comments that although in southern Saskatchewan Upper Cambrian rests directly on the basement, in central Alberta the basal beds are of Middle Cambrian age. He recognized the coarse clastic facies of the Williston basin area, the fine clastic facies of east-central Alberta and the carbonate facies of southwestern Alberta. Gussow submitted in his paper a valuable summary of fossil evidence from a number of wells drilled in southern Alberta.

In 1957 Raasch and Campau described a Middle Cambrian section which was partly cored at California Standard Parkland No. 4-12, tp. 15, rge. 27, W. 4th mer., describing the faunal zones encountered and reinterpreting Gussow's stratigraphic succession. Raasch recognised a Middle Cambrian fauna at Texaco Wizard Lake No. B-3 (l.s. 15, sec. 21, tp. 48, rge. 27, W. 4th mer.) ^{data of} (personal communication).

Granite Wash

Articles by Sproule (1956), Baillie (1956), Goodman (1956) and Greenwalt (1956), dealing with the geology and oil and gas prospects of the Granite Wash of northwestern Alberta (which extends into a part of the area of this paper), were a part of a symposium published in the October and November, 1956, issues of the Journal of the Alberta Society of Petroleum Geologists.

Middle Devonian

To date detailed Middle Devonian geology of the map area has not been published. The writer described the regional stratigraphy, subdivisions, and oil and gas prospects of these beds in 1957 and in more detail in 1959 in a few unpublished reports. Regional stratigraphic papers by Webb (1951), Warren and Stelck (1958) and Sikabonyi (1959) refer generally to the area.

McGehee (1949) described and gave the name of Elk Point to the strata penetrated in deep wells some 130 miles east of the map area. Crickmay (1954) who subdivided the group into nine members, outlined a correlation across western Canada reaching as far west as the Imperial Grosmont No. 1 well (l.s. 13, sec. 17, tp. 67, rge. 23 W. 4th mer.), 50 miles east of the map area. Belyea (1952) described the geology of the Elk Point Group east of the map area. Law (1955) described the Middle

Devonian and younger geology of northwestern Alberta immediately north of the map area but did not attempt a correlation between his area and central Alberta.

HISTORY OF NOMENCLATURE

Middle and Upper Cambrian of the map area was originally subdivided into eight lithologic units, from "a" to "h", in ascending order, by the writer in 1957. The same subdivision is maintained in this paper.

The term Granite Wash is a lithologic name applied by the petroleum industry to a unit of basal Paleozoic clastic beds overlying the Precambrian in northern Alberta. The term was originally used by John Newland in 1950 with reference to the basal sandstone of the Peace River country (unpublished). Subsequently it appeared, used correctly and incorrectly, in the papers of the Granite Wash symposium (ASPG 1956).

The term Elk Point Formation was applied by McGehee (1949) to the strata which underlie the Devonian Waterways Formation and lie "on the Ordovician, Cambrian or pre-Cambrian rocks" in eastern Alberta. The type locality given was the deep wells near the town of Elk Point. Crickmay (1954) subdivided the formation into nine members. Elk Point was raised to the status of a group by Belyea in 1952 and the term is used in this way in this paper. Law (1955) extended the term into northwestern Alberta and subdivided the group into an upper Watt Mountain Formation, and an underlying Muskeg Formation, laterally grading into the Presqu'ile Dolomite, Keg River Formation, and Chinchaga Formation. Neither Crickmay's nor Law's terminology in entirety is applicable in the map area. On pages 49 to 51 a tentative lithologic correlation is outlined between the Elk Point of the map area and north-western and eastern Alberta, thus relating Law's and Crickmay's sections.

The term Gilwood Sandstone is used in this paper for a sandstone member of the Watt Mountain Formation. It was described as such originally by Guthrie (1956)

at the type locality, Stanolind Giroux Lake No. 1 (l.s. 6, sec. 20, tp. 65, rge. 20, W. 5th mer.)

A new term, the Assineau Sandstone is introduced by the writer for another sandstone sheet within the Elk Point Group; the sandstone is described on page 38.

GENERAL STRATIGRAPHY

The area of north-central Alberta is underlain by an average thickness of 7500 feet of marine Paleozoic and Mesozoic deposits. The lowermost of these are discussed in this paper; they include Cambrian and Middle Devonian sediments and the basal Granite Wash. Cambrian beds are 1600 feet thick in the south, but northward are truncated by the pre-Devonian unconformity. Cambrian rocks in the south and Precambrian rocks in the north are overlain by progressively younger Devonian beds westward, thus the Middle Devonian deposits of the Elk Point Group are 1000 feet thick in the east and are lapped over by younger Devonian rocks in the western part of the map area. The Granite Wash is a basal Paleozoic bed of varying thickness underlying the Middle Cambrian in the south and progressively younger Devonian sediments in the northeastern and northwestern portions of the map area, respectively.

PRECAMBRIAN

The Precambrian basement underlies Cambrian in the southern, Middle Devonian in the northeastern, and Upper Devonian in the northwestern parts of the map area, with a thickness of Granite Wash developed locally in between. Basement is at a depth of 5000 feet, and more than 11,000 feet, in the northeast and southwest, respectively.

White, pink, orange, and salmon colored granite, biotite granite, and/or gneiss comprise the top of the basement where penetrated. Chips of a dark gabbroid rock and green amphibole were observed in the bottom sample from California Standard Gulf Kaybob No. 5-35 (tp. 62, rge. 18, W. 5th mer.). A possible Proterozoic belt is indicated at Hudson's Bay Union Liberal No. 7-33 (tp. 68, rge. 22, W. 5th mer.) where, below the base of a typical lowermost Cambrian Unit "a", 330 feet of sediments (?) were encountered. These were described by the Hudson's Bay Oil Company Geological Department (personal communication--samples were not available to the writer), as pink and white, fine- to coarse-grained sandstone and siltstone, locally glauconitic, interbedded with dark green shale and thin layers of dolomite and limestone with brown hematite, talc, muscovite and chlorite common throughout. The electric log character of the sequence does not resemble that of the usual Precambrian, nor the Cambrian sequence of the area.

GRANITE WASH

The term Granite Wash is defined on page 5, and is applied in this study to the basal clastic interval overlying the Precambrian. The age of the Wash in the area of the study varies from Cambrian or older in the south to as young as possibly Middle Devonian in the east and late Upper Devonian (post-Beaverhill) in the west. The regional character of the Granite Wash is different in the south where it is overlain by Cambrian from that in the north where it is overlain by Devonian beds.

GRANITE WASH(?) OF SOUTHERN AREA

In the south, the lowermost Cambrian Unit "a" rests directly on the basement. Although it overlies a major unconformity it has a remarkably uniform thickness and mature lithology throughout (cf. p. 13). At a few scattered wells however, a basal wash (?) was observed at the bottom of "a".

For example at Imperial Dapp No. 1 (l.s. 5, sec. 29, tp. 62, rge. 1, W. 5th mer.) a basal bed is present which in samples looks like an arkose and is over 30 feet thick (plus 20 feet of the overlying quartz conglomerate). The examination of well cuttings with a binocular microscope does not give clues as to the structure of this bed; it contains gypsum, glauconite, pyrite, and green and grey-green locally waxy shale, associated with the granite-like chips, which have similar lithology to that of the immediately underlying basement rock.

A similar arkose-like deposit at the base of the Cambrian was observed at Home Union Virginia Hills No. 9-20 (tp. 65, rge. 13, W. 5th mer.) and at California Standard Gulf Kaybob No. 5-25 (tp. 62, rge. 18, W. 5th mer.) where it is 25 and over 50 feet thick, respectively. At these wells it appears to be a more mature sandstone than at Dapp, with a higher content of quartz and more rounded grains.

The basal bed may represent a reworked regolith accumulated locally in the lows of the Precambrian unconformity, or regolith preserved in depressed localities and cemented by shallow marine deposits at the beginning of the Cambrian transgression. On the other hand, the lack of the maroon colour, so typical of the lowermost Cambrian

elsewhere, indicates that it might be a remnant of a still older sediment, truncated by the pre-Middle Cambrian peneplanation.

GRANITE WASH OF NORTHERN AREA

In the north, the Granite Wash underlies consecutively younger onlapping Devonian beds: in the northeast it underlies the Red Bed Unit; in the north-central part of the map area, where the Granite Wash coincides locally with the basal Assineau sand, it underlies the Clastic and Evaporitic unit, in the northwest the Granite Wash merges into, and coincides with the Gilwood and/or younger sands, discussed on pages 38 to 46. Throughout the northern area the thickness and the lithology of the Granite Wash changes abruptly on the local scale; e.g. in the Red Earth Creek area (tp. 87, rge. 8, W. 5th mer.) it changes from 15 to 105 feet within a distance of one mile.

The Granite Wash material of the northern map area usually consists of sandstone, shale and siltstone. In some places it is arkosic; in some places it is very poorly sorted and contains shale and siltstone intermixed with coarse sandstone; in still other places it is a well sorted sandstone interbedded with shales. The shales are green, red and grey, and locally bright green and buff; waxy shales (of residual origin?) were also observed. Locally the Granite Wash contains major anhydrite and dolomite beds which grade up into the overlying Elk Point sequence. Intercrystalline porosity development in the Granite Wash sands ranges from poor to excellent and commonly is excellent.

The writer observed Eochara and Sarcella sp., similar to those observed in the Elk Point Group elsewhere (cf. p. 36), at 5610 feet and at 5640 feet below the top of the Granite Wash at Socony Utikuma No. 16-16 (tp. 81, rge. 5, W. 5th mer.). At other wells, although locally a Devonian appearing fauna was observed immediately above, no distinguishable fossils were found within the Granite Wash.

In general, the Granite Wash deposits of the northern area probably represent the erosional material of the pre-Devonian surface, reworked during the onset of the Devonian transgression, and could have originated from the underlying Precambrian rocks and from the marine material deposited in the Devonian sea, and possibly also from the Cambrian sediments undergoing erosion in the south.

Cambrian strata possibly once extended beyond their present northward limit (see p. 31). If so, their remnants might have been scattered in low lying areas of the pre-Devonian surface and could have been subsequently incorporated into the Granite Wash material. Maroon and green shales and siltstones (although not associated with the coarse mica), characteristic of the Middle Cambrian clastics of north-central Alberta, were observed in the Granite Wash at a number of north-eastern wells, but are conspicuously absent approximately west of Range 8, W.5, except along the northernmost margin of the map area. Such distribution roughly coincides with the suggested distribution of Middle Cambrian sea (see p. 26), and adds to the argument that a high in the Peace River area may have already existed in Cambrian time.

CAMBRIAN

(cf. Cross-Sections A, B, and Maps 1 to 8)

In north-central Alberta, Cambrian sediments may be studied extensively from sub-surface data. Northwardly and within the map area, they are gradually truncated by the pre-Devonian unconformity. Westwardly and southwardly they plunge deeply below the younger Paleozoics and were not penetrated to date, although 60 miles to the southwest, they crop out in the western Rocky Mountains (see p. 2). Southeastwardly they may be studied in subsurface in scattered wells (see p. 3).

Within the map area Cambrian control is scattered: the northern wells encountered a deeply eroded Cambrian interval and only lowermost units are present; the majority of southern wells did not penetrate the entire Cambrian sequence.

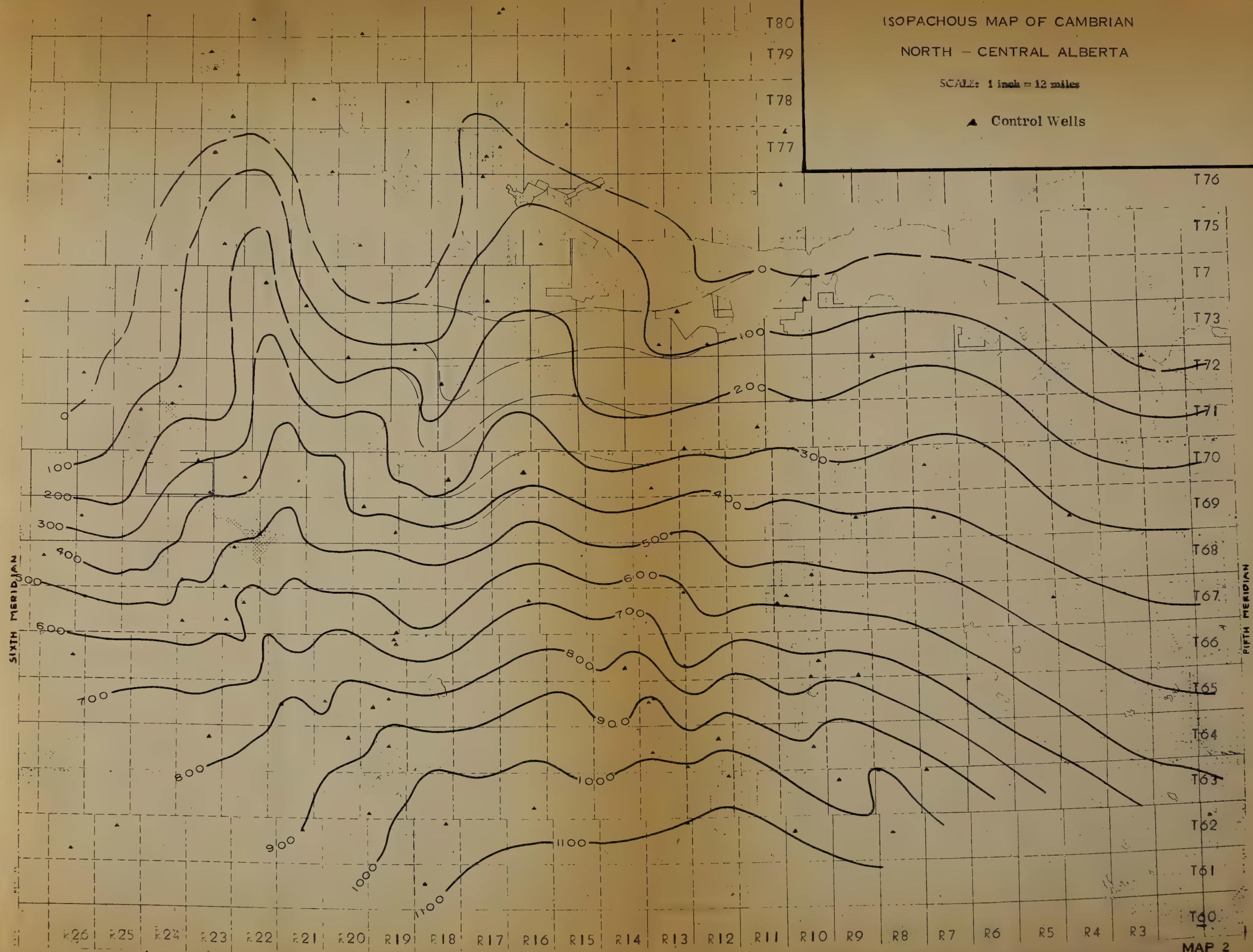
The top of the Cambrian strata is at a depth of approximately 7000 feet in the southeast and 10,000 feet in the southwest. The Cambrian ranges in thickness from zero north of Lesser Slave Lake to over a 1000 feet in the southern part of the map area. On the basis of fossil evidence, although rather scarce to date, the beds are assigned to the Middle and Upper Cambrian (see p. 13). Cambrian beds underlie Devonian rocks and overlie the basement with considerable unconformity. The beds are divided in this paper into eight well defined lithological units from "a" to "h" which are readily distinguishable both in samples and on the electric logs. Where not affected by post-Cambrian erosion, the units exhibit certain uniform lateral gradations of thicknesses and lithologies which appear to be of regional significance. For that reason, the units were studied in some detail. Their description in ascending order follows.

ISOPACHOUS MAP OF CAMBRIAN

NORTH - CENTRAL ALBERTA

SCALE: 1 inch = 12 miles

▲ Control Wells



CAMBRIAN UNIT "a"

(see Maps 1, 4 and 8)

Unit "a" underlies the larger, southern part of the map area. Its erosional limits are indicated on Maps 1 and 4. Unit "a" overlies unconformably the Precambrian basement and underlies Unit "b". Where "b" is absent due to erosion, it underlies the basal Elk Point directly. The top of Unit "a" is placed at the top of a distinctive bed of a highly micaceous shale below the sandy Unit "b". The contact is sharp and well marked throughout the major map area and is easily distinguishable on the electric logs by a characteristic rise of self potential and resistivity values.

In the north, however, the top of Unit "a" is difficult to establish where either "b" is absent due to erosion, and partly eroded "a" underlies the basal Devonian Assineau Sandstone (see stippled area on Map 10); or where the upper subunit is not developed and "a" is overlain by the "b" sandstone or by the Assineau Sandstone (see dotted area on Map 4).

Lithologically, Unit "a" may be subdivided into an upper subunit and the main subunit (see Fig. 1). The upper subunit contains typically maroon and green, and locally red, abundantly micaceous, glauconitic, flaky to splintery shale with minor lenses of buff siltstone. It grades down into the main subunit which generally contains similar shales, interbedded with major quartz sandstones and thin layers of dolomite. Following is a detailed description of the lithology of "a".

The sandstones of the main subunit of "a" are colourless, grading to pink and red due to hematitic coating, locally with a matrix of maroon and less commonly green shale and locally unconsolidated. The sands range from very fine to conglomeratic. Sorting is from fair to more commonly poor, and generally increasingly poorer toward the base. The grains grade from rounded to angular. The lateral distribution of well sorted and fine sandy facies and the poorly sorted, coarser sandy facies within the main subunit appears to follow indistinct southwesterly striking belts. Large angular and rounded pebbles are common at the base. Coarse muscovite flakes associated with coarse, secondary crystals of chloritic matter are abundant and



FIGURE 1

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AM2 4802
EDMONTON Tel No
23598

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SPONT POTEN	LOG POROSITY	% LITHOLOGY	RESISTIVITY
-------------	--------------	-------------	-------------

PLASTIC & EVAPORATIVE UNIT
UPPER ZONE

shale zone

1. FINE BED UNIT

MBRIAN
UNIT "A"

UNIT "d"

UNITS

UNIT "b"

UNIT 10

PRECAMBRIAN

LHESTONE tan chalky. Anhydrite. SHALE grey limy, anhydritic.

SANDSTONE clear quartz, medium-grained to conglomeratic, poorly-sorted, angular grains
interbedded with: **SHALE**, grey, slightly limy, anhydritic; **ANHYDRITE + GYPSUM**

SILTSTONE: light grey, clayey, interbedded: SANDSTONE + ANHYDRITE as above.

ANHYDRITE white, buff, gray, crypto- to finely crystalline

SHALE red, green gray, fissile interbedded: ANHYDRITE as above.

DOLomite: tan, crypto-tan, finely crystalline, locally argillaceous
intubed. SHALE: tan, dolomitic, silty and GYPSUM

SHALE
ANHYDRITE light gray, green, soft anhydritic
write to soft, very finely crystalline
anhydrous to gray, very finely crystalline, blocky, green, DECAHEDRAL and finely crystalline, small...

DOLOMITE cream to grey, finely crystalline, with common QUARTZ grains - medium size
 (SPHAL) light grey, green, grading down to dark green; fissile grading down to a hard
 SANDSTONE grading to pink + red; medium to coarsely grained, well to poorly sorted, angular to rounded grains.
 DOLOMITE grading to ANHYDRITE, red, light green and pink locally slightly
 finely crystalline dolomite + anhydrite.

SANDSTONE clear to red ^h felspathic + quartz, fine-grained to conglomeratic, angular grains above
interbedded: poorly-sorted + well sorted; locally [rounded below]
unconsolidated, locally dolomitic
SHALE green + red, loc. sandy + dolomitic; DOLOMITE sandy; ANHYDRITE

LIMESTONE buff, finely crystalline with QUARTZ grains, medium grained to conglomeratic, rounded.
DOLOMITE red, finely crystalline, argillaceous grading to
SHALE red, blocky dolomitic
GALSS grey, blocky

light grey, medium to coarsely recrystallised. loc. fair intercryst. + vug porosity
DOLomite light grey, finely argillaceous

SHALE green + red + maroon, hard, splintery, locally glauconitic, pyritic, dolomitic
+ micaceous + micro-micaceous.

interbedded: SANDSTONE white, very fine-grained, micaceous, glauconitic, slightly dolomitic

DOLOMITE cream, finely crystalline, slightly sandy (fine-), silty + micromicaceous

SANDSTONE ^{grading to:}
cream-grey fine-grained, clomitic → grading to locally DOLOMITE
interbedded SHALE as before.

" red

SHALE green-gray splintery

+ DOLOMITE green very finely-crystalline argillaceous

SANDSTONE green-grey, coarsely recrystallised
white-pink fine to medium-grained

SHALE light green flaky, grading

to green fissile

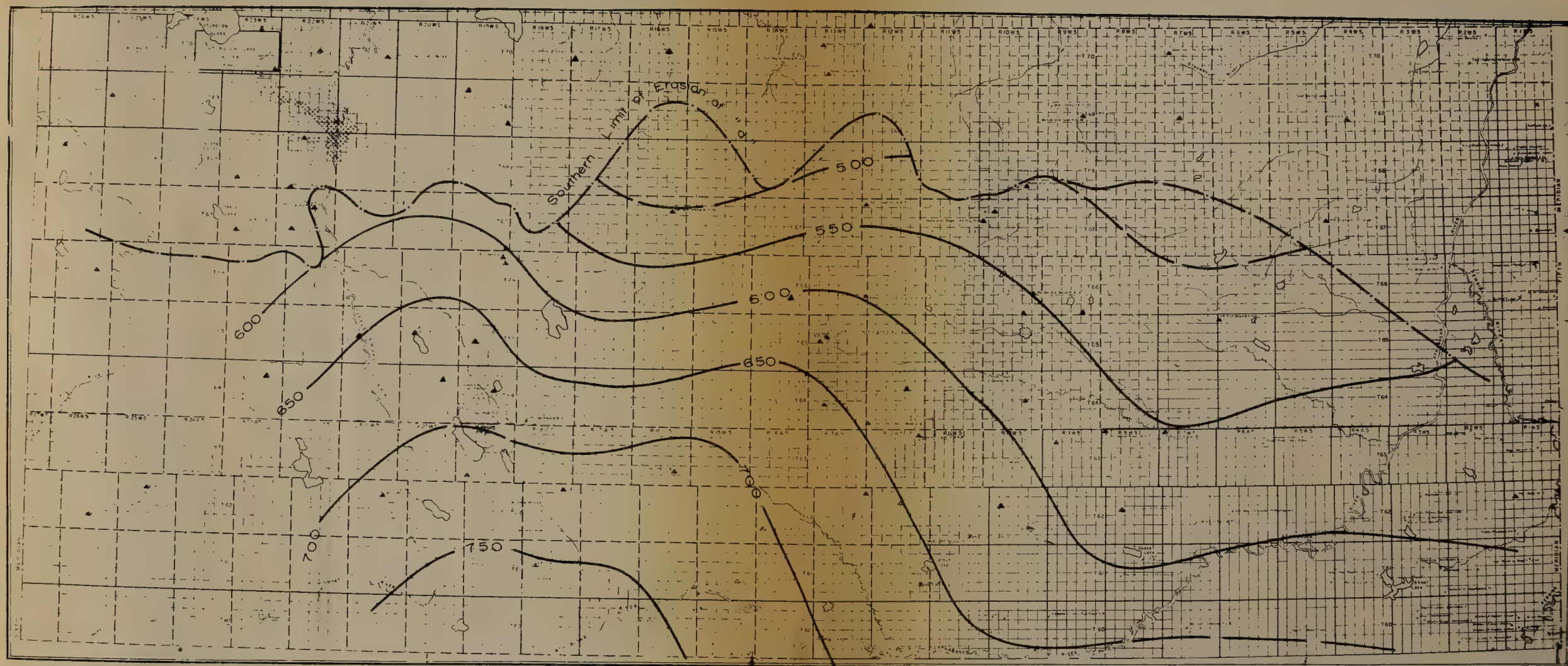
DOLOMITE light grey finely crystalline, very sandy (fine-grained), grading to:
cream to red, variably recrystallised

SANDSTONE cream to red, finely to medium crystalline slightly argillaceous grading to:

white finely-grained well-sorted
{ medium to conglomeratic, grading to Quartzite
poorly sorted, subangular grains, locally unconsolidated interbedded SHALE

white to pink medium to conglomeratic, poorly-sorted rounded grains grading to Quartzite
Loc: poor to excellent intercrystalline porosity. Locally unconsolid. Splintery locally dolomitic, micaceous SILTSTONE

- No samples of basement.



ISOPACHOUS MAP OF NON-ERODED MIDDLE CAMBRIAN INTERVAL

MAP 3

COMPRISING UNITS: "a", "b", "c" & "d"

NORTH - CENTRAL ALBERTA

SCALE: 1 inch = 12 miles

▲ = control

ISOPACHOUS MAP OF NON-ERODED MIDDLE CAMBRIAN
UNITS "A" AND "B" AND GENERALIZED FACIES
MAP OF UNIT "B"

NORTH — CENTRAL ALBERTA

SCALE: 1 inch = 12 Miles

sixth meridian

fifth meridian

LITHOFACIES OF UNIT "b":

SAND CONTENT > 75%

Unit "b" predominantly sandy (at most wells contains over 85% sandstone) locally slightly gypsiferous and argillaceous.

CONT. < 75%

SHALE CONTENT < 50%

Unit "b" comprises of shale & sandstone, (at most wells the unit is close to 30% shale interbedded with sandstone and the main shale beds are in the upper part of the unit, the lower part is mainly sandstone).



Entire Unit "b" comprises: thinly interbedded sandstone, shale and locally little carbonate.

SHALE CONTENT > 50%

Unit "b" is chiefly shale with some siltstone and fine, sandy sandstone interbedded.

LEGEND :

..... 100 a
——— 100 b ———

isopachous contour of Unit "a"
isopachous contour of Unit "b"
upper "a" subunit not developed.
the boundary between units "a"
and "b" is transitional

▲ control

MAP 4



glaucanite is common throughout. Gypsum is common in the basal 50 feet. Feldspar is generally missing in the main subunit, and at the majority of wells Unit "a" overlies the Precambrian abruptly. Its lithology (as far as one can judge from the binocular microscope examination of the well cuttings) does not appear to be related to that of the underlying basement. At a few wells, however, a typical sequence of the main subunit grades down into a basal feldspathic bed from 10 to 50 feet thick, which was discussed in the section dealing with the Granite Wash. (Its thickness is included with the thickness of Unit "a" on the isopachous map.)

Along a broad belt joining the Sturgeon Lake field area with the Kaybob field area the main subunit of "a" is thicker and considerably more sandy than elsewhere. It consists there almost entirely of a white or pink grading to red quartz sandstone with local minor argillaceous matrix; at some wells in that area this sand is very fine grained to conglomeratic, rounded to subangular, typically poorly sorted (e.g. Sinclair Canadian Atlantic No. A4-1, l.s. 1, sec. 14, tp. 70, rge. 21, W. 5th mer.); at others it is very fine to fine grained, subangular, glauconitic, and well sorted, e.g. H.B. Union Liberal Gulf No. 1 (l.s. 3, sec. 5, tp. 68, rge. 22, W. 5th mer.). Also along that trend feldspar was observed as high as 140 feet above the base of Unit "a" at Cal. Standard Gulf Kaybob No. 5-35 (tp. 62, rge. 18, W. 5th mer.).

Thick intervals of excellent intergranular porosity developments are present at most wells in sandstones of unit "a"

The upper shaly subunit of "a" thins gradually northward in the western and central area from a maximum of 80 feet to less than 30 feet, its lower portion becoming sandy and finally merging with the underlying main subunit. Thus, in the dotted area on Map 4 the upper subunit of "a" is not distinguishable and the distinct boundary between "a" and overlying "b" (and so also the porosity barrier between "a" and the porous "b" and/or the porous basal Devonian Assineau sand is absent (see ruled area on Map 11).

As far as one can judge from the control available, the thickness of Unit "a" changes only very gradually across the map area. It decreases from 300 feet in the southwest to 150 feet in the north. An area of distinctly thicker deposition mentioned above extends northwestwardly roughly along the Kaybob-Sturgeon Lake trend. Another less distinct, thick depositional trend is apparent in the central area.

It is indicated on page 23 that Crickmay identified the Middle Cambrian Glossopleura fauna in the upper part of Unit "a" from cores of the Windfall No. 12-36 (tp. 59, rge. 15, W. 5th mer.) well, located along the southern map boundary. The writer observed trilobite fragments and what appears to be worm borings in samples from the upper subunit at a few wells in the map area.

CAMBRIAN UNIT "b"

(see Maps 1, 4 and 8)

Unit "b" is present in the southern part of the map area. Its erosional limits are indicated on Maps 4 and 8.

Unit "b" overlies apparently conformably the upper shaly subunit of "a". The top of Unit "b" is placed at the appearance of a thin (five to 15 foot) layer of bright turquoise and/or maroon, locally dolomitic and sandy shale below the dolomitic and sandy Unit "c". The contact between "b" and "c" is transitional. Below the uppermost layer the Unit "b" is a quartz sandstone, interbedded with varying quantities of shale, siltstone, and dolomite (cf. Fig. 1).

Generalized lithological gradations of Unit "b" are illustrated on Map 4.

In the major eastern part of the area discussed, the upper half of Unit "b" is chiefly red and green, locally dolomitic shale with minor siltstone and sandstone; and the lower half is a quartz sandstone (yellow area on Map 4). The sandstone is generally colourless or light colored, glauconitic, coarsely micaceous, fine- to coarse-grained, mainly subangular to subrounded and typically well sorted, although locally stringers of poorly sorted sand were observed.

Into the east-central area (green area on the map) extends a tongue of uniformly thick, predominantly shaly "b" (less than 20 per cent of interbedded sandstone and dolomite).

Westward, the entire Unit "b" becomes progressively more sandy, thus along a northwesterly belt in the west and in a small patch of the central map area, the entire unit is a uniform sandstone (see pink areas on Map 4). The sandstone is clean, quartzose, fine to medium grained, well sorted with angular to subangular grains. Glauconite and mica were not observed. Scattered gypsum cement is common. At one well located along the axis of the western sandy belt, namely Shell Sturgeon Lake No. "SB" 1-12 (tp. 69, rge. 22, W. 5th mer.) the sand is highly feldspathic.

Farther to the west the shaly content again increases.

In the southernmost map area (hatched on Map 4) Unit "b" is comprised of repeatedly inter-layered sandstone, siltstone, shale and some dolomite. At Imperial Dapp No. 1, in the southeastern corner of the area, the sandstone is fine to coarse-grained, poorly sorted and contains angular grains. At the southwestern wells it is generally finer, grading to siltstone.

Good to excellent intercrystalline porosity development is present in the sandy intervals of Unit "b" in the yellow and orange areas of the map, except at a

few localities in the west where a gypsum cement is present or in the stippled southern area where it is silty and shaly.

The shaly Unit "b" is just slightly less than 60 feet thick in the south-central area. From there it increases to approximately 100 feet in the north and south where it is more sandy. It attains a thickness of 160 feet along the highly sandy belt in the west. Generally, the variations in thickness appear to be related to the sand content of the unit (see Map 4).

The writer observed trilobite fragments in samples in the upper part of Unit "b", at 8270 feet, at Home Imperial Fina Grizzly Mountain No. 6-20 (tp. 70, rge. 7, W. 5th mer.).

CAMBRIAN UNIT "c"

(see Maps 1, 5 and 8)

Unit "c" underlies the southern part of the area discussed. Its erosional margins are indicated on Maps 5 and 8. Unit "c" appears to overlie Unit "b" with a sharp contact in the east and a transitional contact in the west. The top of Unit "c" is placed at a sharp rise of the carbonate content, easily distinguishable in samples and on electric logs in the major part of the map area (cf. Fig. 1). In the east, where the overlying Unit "d", as well as "c" are predominantly shaly, the contact is, nevertheless, well marked by a sharp fall of the resistivity and a sharp rise of the self potential on the electric logs.

Conspicuous lateral lithologic gradations of Unit "c" are illustrated on Map 5:

In the eastern (green) part of the map area an estimated 90 per cent of the unit is a maroon to green, abundantly and coarsely micaceous and locally slightly limy shale. Traces of pyrite were observed. At the base a bed, 3-25 feet thick, of white to red argillaceous, lithographic to finely crystalline dolomite is usually present.

ISOPACHOUS & GENERALIZED FACIES MAP OF
NON-ERODED MIDDLE CAMBRIAN UNIT "c"

NORTH-CENTRAL ALBERTA

LEGEND



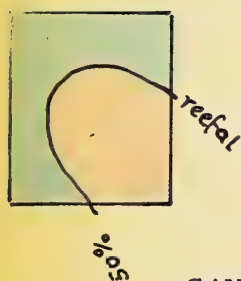
isopachous contour of Unit "c"



control

Lithological Facies

CARBONATE content 80% - 100%



Dolomite and/or Limestone, mainly crypto-to finely crystalline with scattered zones of poor porosity developments. (At most wells carbonate content is close to 100%.)

A major central part of the unit (over 50% of the total thickness) comprises light colored, medium to coarsely sugary, reefal(?) dolomite with excellent intercrystalline and vuggy porosity developments.

SANDY DOLOMITE, SAND CONTENT 20% - 50%



Mainly very finely to medium crystalline, sandy dolomite. Shale generally absent. Scattered zones of fair to good intercrystalline porosity developments.

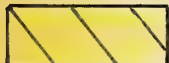
DOLOMITIC & LIMY SANDSTONE and SOME INTERBEDDED SANDY DOLOMITE OVERALL SAND CONTENT MORE THAN 50%.

Mainly light colored, fine to coarse grained, dolomitic sandstone with local beds of sandy dolomite as above.

Shale stringers absent in the west, increase eastwardly:



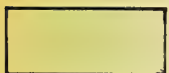
Shale content less than 20%. Fair to good intercrystalline porosity developments



Shale content over 20%. Porosity developments are poor to absent.

INTERMEDIATE ZONE between facies as above and as below.

SHALE CONTENT OVER 60%



Mainly shale and some interbedded very fine sandstone siltstone and carbonates.

Progressively westward grading into the yellow area the carbonate content and also the silty and finally sandy content increase. Porosity developments are poor to absent.

In the area marked in yellow on Map 5, Unit "c" is a light colored, highly dolomitic, glauconitic and coarsely micaceous, fine- to medium-grained, well sorted sandstone, locally grading to finely and medium crystalline, highly sandy dolomite. Disseminated pyrite was observed. Shale stringers there are less conspicuous progressively westward and in the westernmost yellow area the upper part of "c" is a grey and buff, grading to brown, very finely to medium crystalline dolomite which is silty, finely sandy and/or contains abundant "floating" quartz grains. The lower part of "c" in the yellow area is a fine- to coarse-grained, poorly to well sorted light colored, highly dolomitic sandstone, interbedded with little shale. Within the orange area, fair to good intercrystalline porosity developments were observed in the coarser sandy and dolomitic intervals of the unit.

Still farther west the sand content of Unit "c" gradually decreases, and finally the entire unit grades into a clean dolomite (blue area on Map 5), which is buff to brown, crypto- to finely crystalline with local poor porosity development. In the northwesternmost area it contains a central portion 20 to 50 feet thick of white, medium to coarsely recrystallized, sucrose, locally reefal dolomite with stromatoporoid-like structures, locally with "floating" quartz grains which contains excellent intercrystalline and vug porosity developments (cf. violet areas on Map 5).

Farther west, Unit "c" becomes thinner, and comprises brownish-red, very finely to finely crystalline dolomite, interbedded with shale, and grey to brown, very fine grained, silty and glauconitic sandstone.

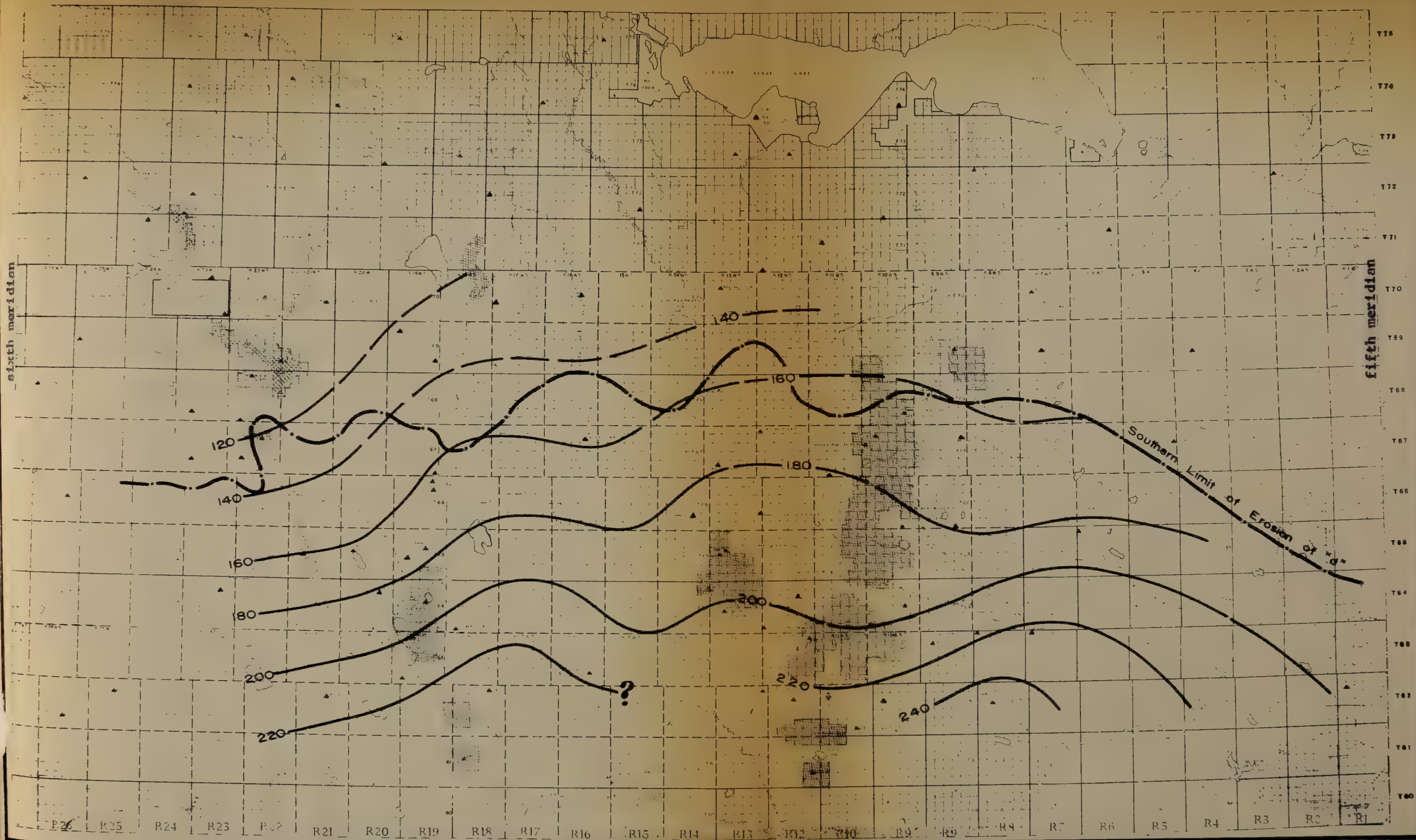
Isopachs of Unit "c" are illustrated on Map 5. The Unit is over 100 feet thick in the highly sandy central area, and gradually decreases to less than 60 feet in the shaly southeastern area, and also in the dolomitic western area. The westward decrease in thickness is probably in part the result of the loss of the lowermost 25 feet of sandy "c" to the underlying Unit "b". The local thickening of Unit "c" in the northwest coincides with the local reefal build-ups.

Fine trilobite fragments and fragments of thin brachiopod shells were observed by the writer in the cuttings from Unit "c" between 1060 and 11,090 feet at Amerada Crown A-1 No. 1029 (tp. 68, rge. 26 W. 5th mer.).

CAMBRIAN UNIT "d"

(see Maps 1, 6 and 8)

Unit "d" underlies the southern one third of the area discussed. Erosional margins of the unit are indicated on Maps 6 and 8.



LEGEND:

▲ well control

120' isopach of Unit "D"

ISOPACHOUS MAP OF NON-ERODED MIDDLE CAMBRIAN UNIT 'D'

NORTH-CENTRAL ALBERTA

Scale: 1 inch = 12 miles .

MAP. 6

The contact of Unit "d" with the underlying dolomitic Unit "c" is sharp throughout the map area. The top of Unit "d" is placed on the top of the uppermost major shale bed below the carbonates of Unit "e".

The lithology of Unit "d" is remarkably uniform (cf. Fig. 1). It contains grey-green, green, maroon, red, hard and splintery shale, with abundant fine and coarse muscovite mica flakes and locally contains layers of very fine-grained sandstone. It is locally glauconitic, locally slightly dolomitic and sandy. Minor lenses of light grey to white crypto-crystalline limestone and/or dolomite are interbedded, and increase to the southeast, particularly in the uppermost part of the unit.

The thickness of Unit "d" decreases from over 220 feet in the south to 140 and 120 feet in the north. The isopach gradient is considerably larger in the west and east (3.3 feet per mile on the average) than in the central map area (less than one foot per mile).

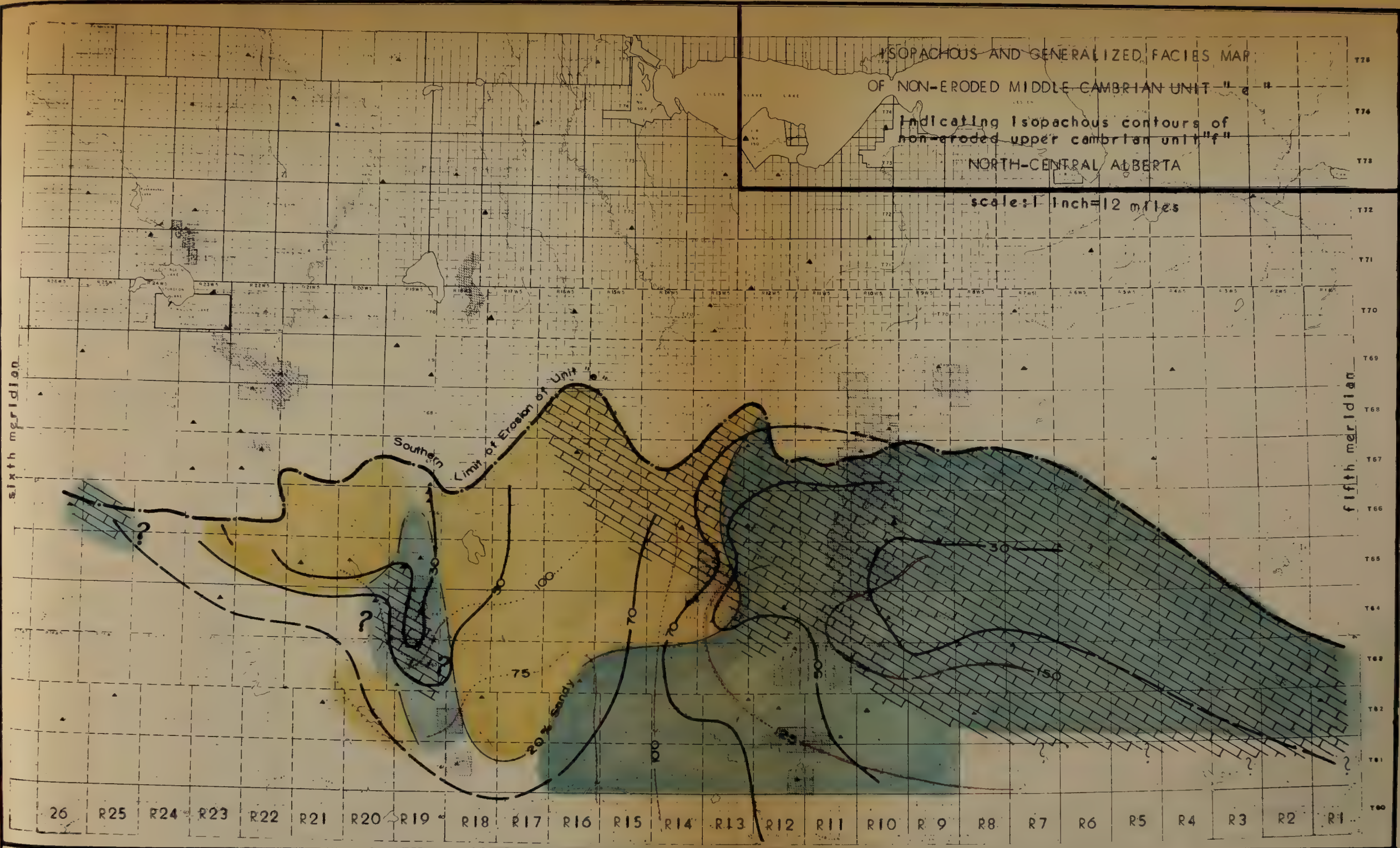
Fossil fragments were observed in Unit "d" at several wells, and at Imperial Dapp No. 1 in the southeasternmost corner of the area trilobite fragments, a Lingula, and scattered spines and other undiagnosed fragments were observed.

CAMBRIAN UNIT "e"

(see Maps 1, 7 and 8)

Unit "e" underlies the southern part of the southernmost area discussed. Its erosional limits are indicated on Maps 7 and 8.

The boundaries of "e" with the underlying shaly Unit "d" and the overlying sandy Unit "f" are well defined. Generally, the top of Unit "e" is placed at the top of a distinctive carbonate section below the "f" sandstone or below the basal "f" siltstone and/or shale. At the wells where "e" is appreciably sandy the contact with "f" is typically gradational across some 10 feet or so, but is quite conspicuous both on the electric logs and in the samples.



LEGEND:

MAP 7

▲ Control

30 Isopachous contour of Unit "e"

75 Isopachous contour of Unit "f"



Mainly dolomite, sandy to very sandy

Mainly dolomite, non-sandy to sandy

GENERALIZED FACIES OF UNIT "E":



Mainly crypto- to finely crystalline

Mainly medium to coarsely recrystallised, sugary, fragmental oolitic

For example at Phillips Kaybob No. 7-22 (tp. 64, rge. 19, W. 5th mer.) a sharp contact is present between the coarsely recrystallized dolomite of Unit "e" and the overlying "f" sandstone; at Imperial Virginia Hills No. 6-36 (tp. 63, rge. 12, W. 5th mer.) a 30 foot layer of the silt is present on the top of the "e" dolomite; and at Union Hudson Bay Virginia Hills No. 9-20 (tp. 64, rge. 13, W. 5th mer.) a transition between the sandy "e" dolomite and the underlying "f" sandstone was observed.

As mentioned, Unit "e" is predominantly a dolomite (cf. Figs. 1 and 2). Facies changes are indicated on Map 7.

In the south-central part of the map area and southward, at Fina Stanolind H.B. Windfall No. 12-36 (tp. 59, rge. 14, W. 5th mer.) and Fina Stanolind H.B. Sundance No. 15-29 (tp. 55, rge. 17, W. 5th mer.) it is a tan to brown crypto-crystalline dolomite.

Northwardly and northeastwardly and also along indistinct trends of the west it grades abruptly into light colored, medium to coarsely sugary (reefal?), fragmental and oolitic dolomite; in the southeast, at Imperial Dapp No. 1 Unit "e" is a coarse dolomitic breccia in a light green, finely crystalline dolomite matrix.

In the central map area the dolomite becomes northwardly silty, and farther north progressively finely, medium, and coarsely sandy.

Good to excellent, intercrystalline and locally also vug porosity developments are generally present throughout Unit "e" where it is coarsely dolomitic and/or coarsely sandy (cf. ruled area of Map 7).

The isopachs of Unit "e" are illustrated on Map 7. The Unit is between 30 and 85 feet thick where not affected by the pre-Devonian erosion. The regional thickening in the central map area appears to be related to the rise of the sand content. Local trend of greater thickness in the west-central area might be related to reefal build ups, or perhaps, to the local diastems (see p. 20). No recognisable fossils were observed in the well cuttings of Unit "e" examined by the writer.

CAMBRIAN UNIT "f"

(see Maps 1, 7 and 8)

Unit "f" underlies the southernmost area discussed. Erosional limits of the unit are shown on Map 8.



FIGURE 2

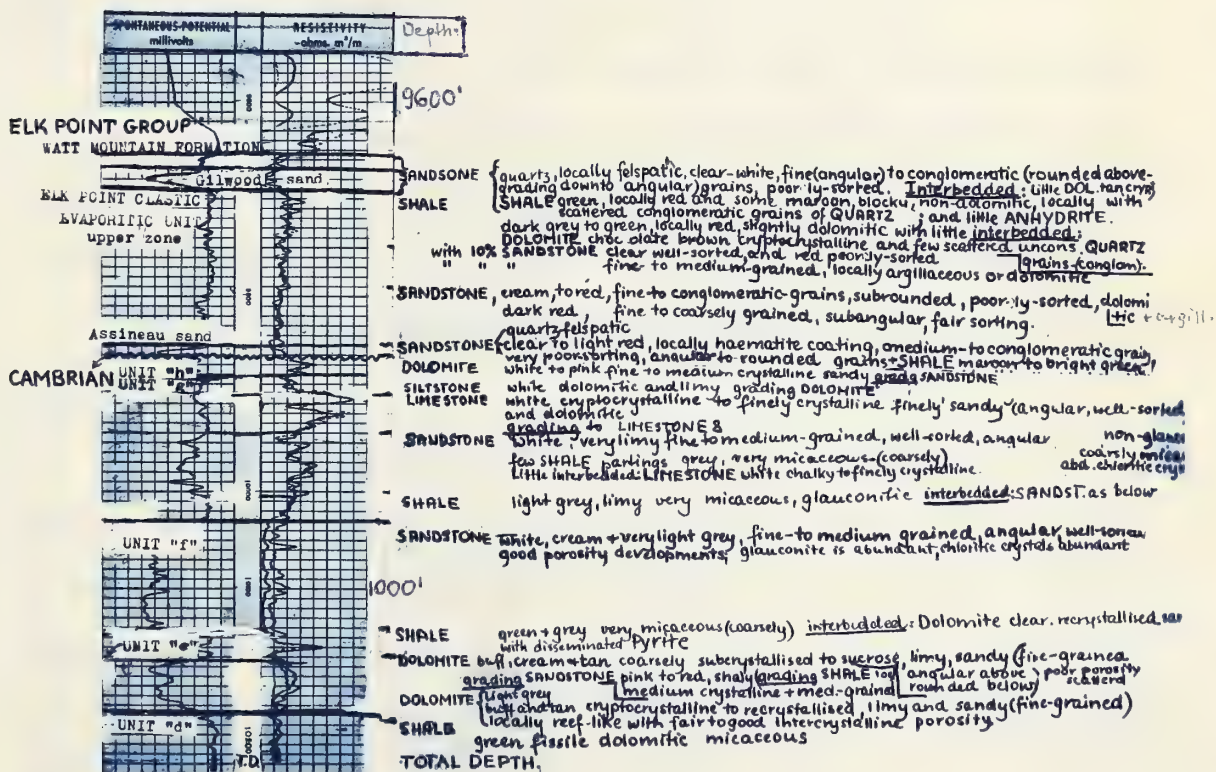
LITHOLOGY LOG - INTERPRETIVE TYPE

L.s. 10, sec. 6, tp. 64, rge. 12, W 5th mer.

IMPERIAL SHELL BURNTWOOD No. 12-6-64-12

K.B. 3780'

T.D. 10270'.



As indicated ~~on above~~, Unit "f" overlies Unit "e" with a locally abrupt, locally gradational contact. The contact with the overlying "g" is abrupt and is placed on the top of the uppermost sandstone below "g" limestone or below the basal "g" siltstone.

Unit "f" consists of a remarkably uniform bed of white, grading to pink, very well sorted, angular to subrounded, dolomitic and locally limy, locally glauconitic, coarsely micaceous sandstone with abundant bright green authigenic crystals of chloritic matter (cf. Fig. 2). It is medium grained to coarse grained in the west (with local stringers of coarser, rounded grains) progressively grading to a very fine-grained sandstone in the east with interbedded siltstone and silty dolomite in the southeast. Intercrystalline porosity developments, grading from fair to commonly excellent are present throughout the entire interval in the central and western map area and are poor to absent in the east and southeast (cf. Map 1).

At the base of Unit "f", a diastem may be present. Locally, at the base is a bed of grey, soapy appearing siltstone, interbedded with, and locally grading into, light grey and green shale. The bed is between 0 and 30 feet thick (e.g. it is 30 feet thick at the Burntwood No. 12-6-64-12 well, illustrated on Fig. 2).

The thickness of non-eroded Unit "f" is between 70 and 155 feet in the map area.

The isopachous contours (not fully illustrated on Map 7) parallel in reverse those of the underlying "e". Thus, "f" is over 150 feet in the east where "e" is under 30 feet thick, and "f" is thinner than 100 feet in the central map area where "e" is mainly over 50 feet thick.

Relating this to the fact that the contact between the two units is locally transitional, it may mean that where "e" is thicker and "f" thinner, the carbonate facies persisted longer and vice versa.

On the other hand if diastems are present at the top of Unit "e" (as indicated above) the coincidence of thicker "e" - thinner "f" may indicate the deposition of "f" on an unevenly eroded surface of "e". Because of this and also because another possible diastem is apparent immediately above "f", it is difficult to relate the isopach trends of this unit to any inferred depositional trends.

Black organic remains (trilobite fragments?) were observed in samples from the lower Unit "f" at Mobil Oil Goose Creek No. 10-20 (tp. 62, rge. 8, W. 5th mer.), at 8470 feet and also at 8790 feet, where they are associated with excellently preserved oolites. Crickmay has identified Upper Cambrian fossils approximately at the contact of Units "f" and "g", in the core from the Windfall No. 12-36 well situated along the southern map boundary (see p. 23).

CAMBRIAN UNIT "g"

(see Maps 1 and 8)

Unit "g" is present only at the southernmost wells of the area discussed. Its erosional margins are indicated on Map 8. The top of the Unit "g" is placed, below the "h" dolomite at the appearance of a light coloured, dolomitic and limy siltstone.

Unit "g" consists of a locally developed, basal siltstone, the overlying limestone and the uppermost siltstone (see Fig. 2). Porosity developments are absent or poor, throughout.

The basal layer developed at some wells and possibly indicative of a diastem, is up to 30 feet thick. It comprises green, grey to dark grey, locally limy and dolomitic and "soapy appearing", micaceous siltstone, interbedded with, and locally grading into, very light to bright green and waxy shale (e.g. at Stanolind H.B. Windfall No. 12-36, tp. 59, rge. 15, W. 5th mer. and Home Union H.B. Virginia Hills No. 9-20, tp. 65, rge. 13, W. 5th mer.). At a few other wells this basal bed is interlayered with poorly sorted, fine to conglomeratic clear quartz sandstone with angular to rounded grains (e.g. East Virginia Hills No. 1, l.s. 5, sec. 31, tp. 65, rge. 6, W. 5th mer.).

Above the basal layer, the main part of Unit "g" contains light grey, buff and green, finely sandy, medium crystalline limestone, grading locally to a very limy medium grained sandstone. In the uppermost 10 to 20 feet the sandy grains in the limestone are poorly sorted and reach the conglomeratic size.

Above that, at the top of "g", is a 10 to 20 foot thick bed of a very light coloured, dolomitic and limy siltstone, locally interbedded with layers and/or lenses of limy, red and green shale.

The thickness of Unit "g" where unaffected by pre-Devonian erosion is between 150 and 190 feet.

Dr. C.H. Crickmay has identified an Upper Cambrian fauna (see p. 23) within the upper Unit "g" at the Sundance No. 15-29 well 25 miles south of the map area.

CAMBRIAN UNIT "h"

(see Maps 1 and 8)

Unit "g" is overlain by a uniform bed of light buff grading to pink, cryptocrystalline, grading to medium crystalline, locally slightly silty and glauconitic dolomite "h" (see Fig. 2). It contains scattered good to excellent vug and intercrystalline porosity developments.

The tentative erosional margin of Unit "h" is indicated on Map 1. A complete, uneroded Unit "h" was not observed within or immediately to the south of the map area. The maximum, partially eroded, thickness is 140 and 135 feet at Fina Stanolind H.B. Sundance No. 15-29 (tp. 55, rge. 17, W. 5th mer.) and Fina Stanolind H.B. Windfall No. 12-36 (tp. 59, rge. 15, W. 5th mer.), respectively.

Fossils were not observed in samples from Unit "h" of the map area examined to date.

AGE AND CORRELATION

The paleontological evidence (C.H. Crickmay - personal communication, 1957) for the Middle and Late Cambrian age of Units "a" to "h" is from the cores from Fina Stanolind H.B. Windfall No. 12-36 (tp. 59, rge. 15, W. 5th mer.) and Fina Stanolind Sundance No. 15-29 (tp. 55, rge. 17, W. 5th mer.), located one and 25 miles south of the map area, respectively.

At the Windfall well, at 10,916 feet, within the interval corresponding to the upper part of Unit "a" of this paper, Dr. Crickmay identified ~~Dalmanella sp.~~, Ptarmigania sp., Glossopleura sp., and Alokistocare sp., a typical lower Stephen fauna of Middle Cambrian age. At Texaco Wizard Lake No. B-3 (l.s. 15, sec. 21, tp. 48, rge. 27, W. 4th mer.) 40 miles south-southeast of the map area in an interval corresponding to lower Unit "b", Raasch identified Tonkinella stephenensis, which he considers to be of Late Stephen age (personal communication later mentioned by van Hees, 1959).

A Lingulella sp., which he considers to be of Late Cambrian age was identified by Dr. Crickmay in the core from the Windfall well, at 10,203 feet which corresponds to the boundary of Unit "f" and "g" of this paper. From the Sundance well, he identified Cystidea sp., ind., Lingula sp. ind., Orbiculoidea sp. ind., Platycolpus sp., and Dunderburgia sp., which he also refers to the Upper Cambrian, from 12,224 feet, which corresponds to upper Unit "g" of this report.

The Upper-Middle Cambrian boundary as indicated in this paper was suggested by the writer (Suska, 1957) chiefly on the lithological evidence of a diastem or a small disconformity. De Mille (1958) placed it at the same level. However, the writer does not know of any conclusive evidence based on fossils or otherwise, that this is the correct boundary.

Rocks of uppermost Middle Cambrian age were identified by Raasch (1957) 270 miles south of the map area. He recognised the Pika Formation at California Standard Parkland No. 4-12 (tp. 15, rge. 27, W. 4th mer.) and assigned it to the uppermost Middle Cambrian on the basis of the Thompsonaspis fauna. At Mount Robson, 150 miles southwest of the map area Mountjoy (1962) described the Pika Formation as 500 to 700 feet of interbedded dark, cryptocrystalline, argillaceous limestones and intraformational conglomerates; he assigned the formation to the Middle Cambrian. At the headwaters of Hardscrabble Creek and Smoky River 70 miles southwest of the map area the writer observed 300 feet (top was eroded) of white coarsely crystalline reefal dolomite which was tentatively assigned to the uppermost Middle Cambrian or basal Upper Cambrian and might correspond to the same interval.

Van Hees (1959) attempted a lithologic correlation of the Middle Cambrian strata between the Parkland and the Windfall wells extending the Pika Member westward and correlating it with Unit "e" at the Windfall well. Such correlation would place the Upper-Middle Cambrian boundary where it was placed originally by the writer. It would also indicate that the Pika Member extends as an extremely persistent carbonate bed northwestward, far beyond the Eldon and Cathedral carbonates which shale and sand out considerably farther to the east (cf. p. 3).

If Unit "e" truly correlates with the Pika Formation the boundary between Upper and Middle Cambrian should be left at the top of "e" if Pika is considered Middle Cambrian, and should be placed at the base of "e" if Pika is left in the Upper Cambrian. It is probable, however, that the Pika Formation of the Parkland well does not correlate with Unit "e" of the Windfall well but with the uppermost limy, dolomitic and sandy interval of Unit "d" which is 50 feet thick or so at Windfall and at other wells of the area discussed. If so, Unit "e" would have to be assigned an Upper Cambrian age. In the writer's opinion, the well control between Parkland and Windfall areas is still inadequate for final conclusions to be reached. As far as

the facies data are concerned, the most marked change in the environment of deposition throughout the map area (see pp. 27 to 31) took place after Unit "d" was deposited.

A fact which emerges from the comparison of the basal Cambrian at the Parkland and Windfall wells is that at the Windfall well a lower Stephen fauna was the lowest recorded above the basal Cambrian sands, whereas at the Parkland well the Albertella fauna of the Cathedral Formation is the lowermost. This illustrates a very gentle northward onlap. The continuation of the onlap is illustrated by the facies relationships of the Middle Cambrian units within the map area which appear to point out that the shorelines of Unit "d" probably extended farther to the north than for example those of Unit "a".

PALEOGEOLOGY OF THE PRE-CAMBRIAN SURFACE

As far as one is able to judge from the lithology of the well cuttings and the descriptions of the few available cores, the basement which underlies the map area is comprised mainly of granitic and/or gneissic rocks. A Proterozoic sedimentary belt, that is possibly metamorphosed was penetrated at Hudson's Bay Union Liberal No. 7-33 in the Sturgeon Lake area (see p. 8); others might be present but are not penetrated, to date.

The uniform or gently gradational thicknesses of the lowermost Cambrian units, including the basal unit "a", suggest that, in Cambrian time, the Precambrian surface approximated a low relief peneplain. However, along the Kaybob-Sturgeon Lake belt in the west a gradation to thicker and coarser "a" and "b" arenites might indicate a proximate "high" or a local stream source. At present the basement control there is inadequate and it is difficult to speculate if this "high" is related to a prolongation of the Proterozoic belt indicated (cf. p. 32).

TENTATIVE PRE-DEVONIAN PALEOGEOLOGICAL MAP (INDICATING FACIES)

NORTH-CENTRAL ALBERTA

LEGEND

LITHOLOGY OF SUBCROPPING UNITS:

Crystal and Grain Size:				
ROCK TYPE:	COARSE	MEDIUM	FINE	VERY FINE
CARBONATES, sand content less than 20%	medium to coarsely crystalline colitic fragmental and reefal	finely to medium crystalline	crypto-to finely crystalline	
CARBONATES, sand content between 20% and 40%		finely to medium crystalline		
SANDSTONE grading DOLOMITE sand content between 30% and 60%	medium to coarse	fine to medium	very finely crystalline & silt to finely crystalline and fine-grained	
SANDSTONE, dolomitic and/or limy	medium to coarse well-sorted	POORLY-SORTED locally FELSPATHIC	silt to fine-grained	
SANDSTONE shale content over 20%				
SHALE, over 60%				colours illustrate underlying bed

Porosity Developments of the subcropping units:



Mainly poor to good



Mainly good to excellent

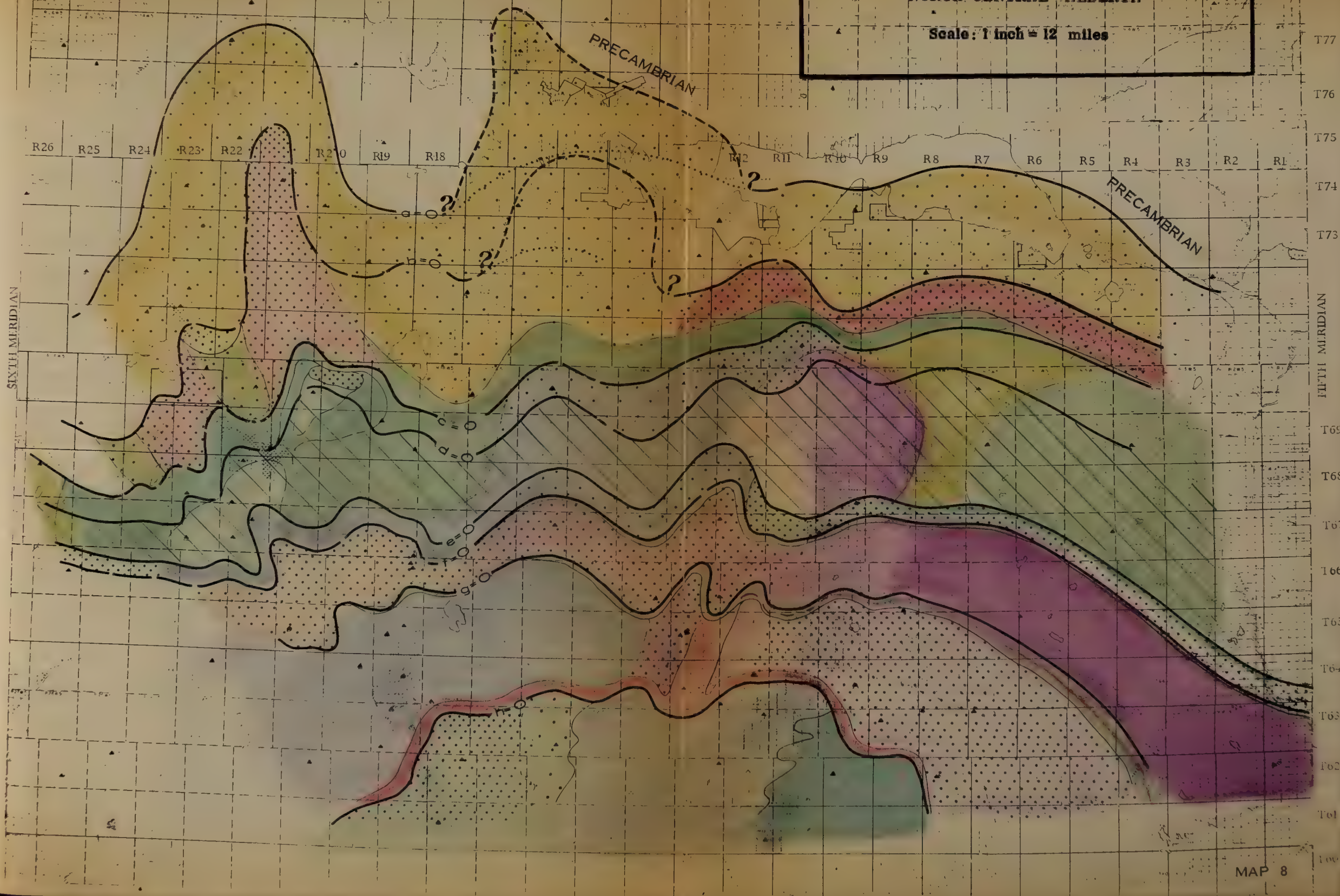
— e—0 — Tentative pinch-out line of Unit "e"

▲ Control wells

TENTATIVE PRE-DEVONIAN PALEOGEOLOGICAL
MAP (INDICATING FACIES)

NORTH-CENTRAL ALBERTA

Scale: 1 inch = 12 miles



The study of the isopachous and facies patterns of the non-eroded Middle Cambrian intervals suggests that during that time the Precambrian surface was tilted or tilting to the south. At the close of the Middle Cambrian the tilt was steeper in the central map area than in the east or west (more than three feet to a mile as compared with less than one foot to a mile, respectively) (see Map 3).

The study of the Upper Cambrian in the area is limited to a partly eroded interval in the southernmost area. Isopachous and facies outlines of the Upper Cambrian units illustrate changes from east to west rather than from north to south. Coarser facies which spread throughout the Late Cambrian sequence indicate that the shallow platform of the Late Cambrian sea was wider than that of the Middle Cambrian sea.

That a Cambrian landmass may have existed in the north-central map area is suggested by the following evidence: (a) such a trend is obtained by extrapolation of the zero isopach of Middle Cambrian units from "a" to "d" (see Maps 3-7); (b) progressively coarser texture of Middle Cambrian beds northward (see discussion on previous pages; (c) higher sand content of some of the Cambrian units in the central map area (see Maps 5-7 and p. 32); and (d) character of the Granite Wash points to a possibility of a granite high in the north-central map area (see p. 11). Thus it is possible that an old high in Cambrian time existed in the general region of the subsequent Devonian Peace River high (see also following pages).

CAMBRIAN DEPOSITIONAL TRENDS

The Cambrian sequence of north-central Alberta has many characteristics of a stable shelf deposit:

The total thickness of the Upper and Middle Cambrian beds is of the order of a thousand feet; individual units are thin, 100 feet thick on the average, and are correlative over long distances;

Gradations from one unit to another are abrupt and probably represent repeated changes between transgressive (and regressive?) phases;

Diastems are suspected (see pp. 20, 21) and if present would indicate brief periods of denudation or non-deposition;

Glaucinite is abundant throughout the Cambrian sequence of the map-area; --according to Krumbein and Sloss (1958) glauconite forms on a stable shelf at times of slow sedimentation;

Mica is abundant in sandstones;--this is considered by Lahee (1941) and Pettijohn (1957), and Krynine (1940) to be a criterion of littoral sedimentation.

A high maturity index and good sorting of the majority of the Cambrian sandstones of the map area indicate a considerably weathered, low lying source, as well as slow deposition and/or repeated reworking. Repeated carbonate beds which extend across the major part of the map area and are prevalent in Upper Cambrian beds indicate periods when detrital supply was low or lacking. A relatively higher clastic content of the lower beds of the Middle Cambrian sequence may mean that transgressive tendencies then prevailed.

To the south and southeast the shelf was probably more depressed as the clastic material there is finer, sorting is generally poorer and highly micaceous shales are common. The southeasternmost area represents a transition into the Cambrian facies of central Alberta (see p. 3).

Possible Sources of Cambrian Detrital Rocks

Two main types of detrital facies appear to be present in the Cambrian sequence of the map area:

The maroon facies is characterized by maroon and green coloured shales, siltstones and fine sandstones, locally interbedded with minor carbonates;

The light-coloured facies is characterized by lightly coloured, coarser clastic rocks, mainly sandstones and some siltstones. They are generally associated with a major or a minor proportion of carbonates.

An example of an invasion of the map area by the maroon facies is the shaly Unit "d" whereas in Units "a", "b" and "c" both facies interfinger.

In the southeastern map area the maroon facies prevails throughout Middle Cambrian, and is practically absent in Upper Cambrian beds.

The writer believes that these two facies could be a result of two different sources of detritus: the light coloured facies probably originated in the Shield, and the maroon facies by the erosion of the Proterozoic rocks perhaps from the Montana high?

A similar light coloured clastic facies is observed in the Middle and Upper Cambrian beyond the map area wherever the Precambrian shorelines were near; e.g. in the Middle and Upper Cambrian outcrops of central and east-central Saskatchewan and in the Upper Cambrian Deadwood formation of the Williston Basin (Borden, 1955).

North (1953) commented on the Middle Cambrian green and maroon shales of the Moose Mountain well, 200 miles south of the map area, that "wherever the Belt series acted as a source of fine clastics, typical maroon and green colour predominates in the sediments" and although this statement appears to be rather broad, one good explanation of a restricted occurrence of these typical colours could be a specific or a similar source area.

A discussion of depositional changes throughout the Cambrian in the map area, unit by unit, follows. It should be pointed out that units were selected on their lithological character, that locally their boundaries appear to be diachronic, and that they cannot be regarded purely as time-based intervals.

The overall lithology of Unit "a", except for a basal arkosic bed which is locally developed (see pp. 9 & 13), is unrelated to the immediately underlying basement rocks. This and also the remarkably uniform thickness of "a", in spite of the magnitude of the underlying unconformity, suggests that the peneplaned Precambrian

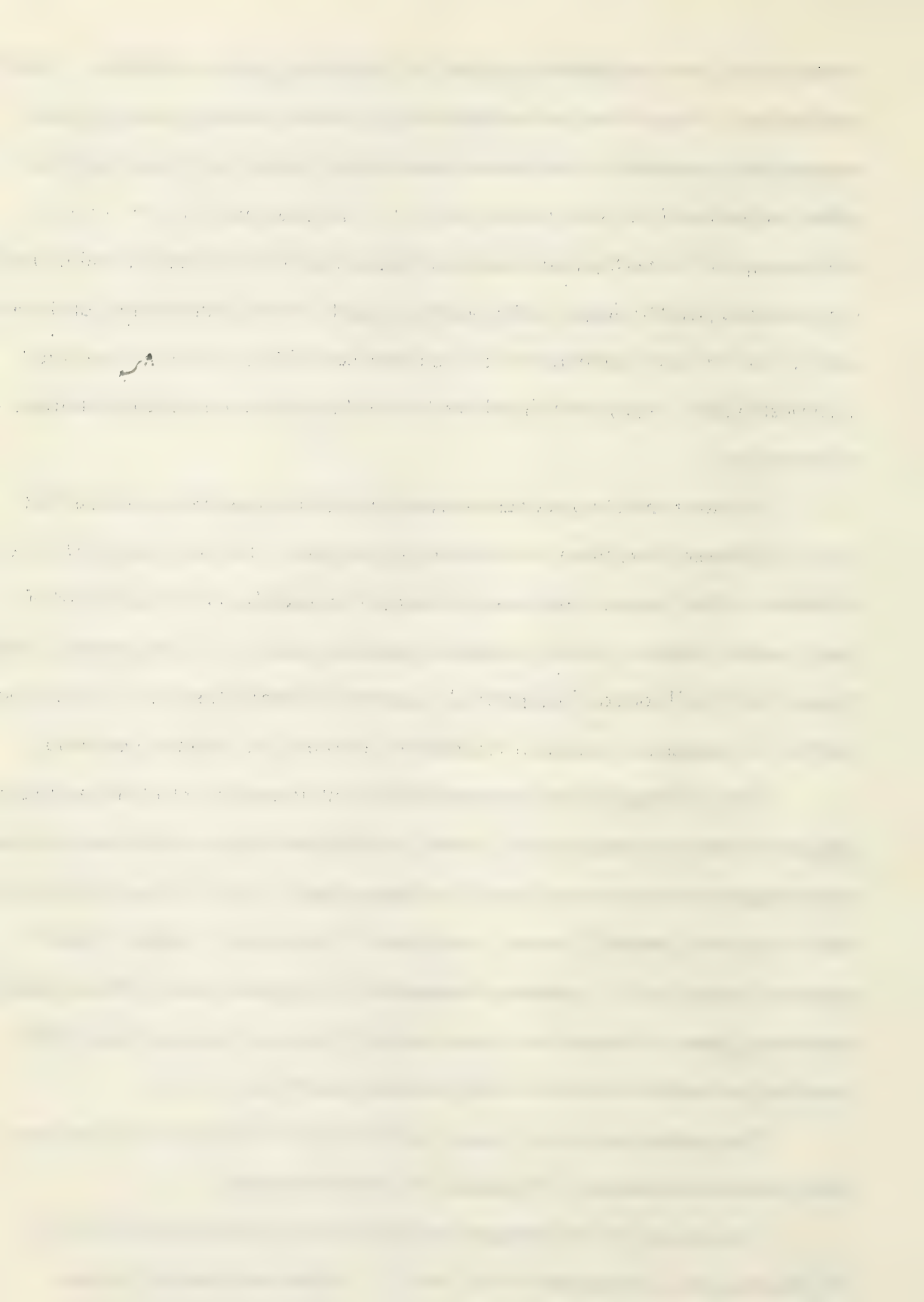
surface slowly provided detritus for Unit "a" under fairly stable conditions. Gentle oscillations of the sea level or variable rates of sediment delivery were probably responsible for repeatedly interlayered quartz sands, maroon and green muds and minor carbonates of the main part of Unit "a". The upper part of Unit "a" is a shale except in the northernmost map area (see dotted area on Map 4), and indicates a quieter and possibly deeper water basinal deposit. A regional thinning of the main part of Unit "a" and "sanding out" of the upper part of Unit "a" to the north (or northwest?) point to proximal shorelines in that direction or a submarine platform of winnowing.

However the Sturgeon Lake-Kaybob belt in the west shows sediments of Unit "a" different from those in the remaining map area: the main part of Unit "a" is thicker in this Sturgeon Lake area, almost entirely sandy, and is comprised of poorly sorted, coarser, locally feldspathic sands (derived from a land mass?), inter-fingered with well sorted, fine-grained, glauconitic (beach?) sands. This configuration for "a" suggests an emergent Precambrian source of an island or peninsula.

The lithology of the lower part of Unit "b" is made up of clean, well-sorted, glauconitic and micaceous (shore?) sands, and indicates again a shallower environment throughout the major map area. In the southeast, where "b" is mainly shaly, a basin of quieter, deeper (?) water is indicated. The southern (stippled, Map 4) map area (where Unit "b" consists of repeatedly interlayered shale, siltstone and/or sandstone), shows the transition to east-central Alberta environment, apparently somewhat less stable than that of north-central Alberta (cf. p. 3).

The predominantly shaly upper part of Unit "b" indicates that the shore-lines probably receded again throughout the major map area.

The anomaly of the Sturgeon Lake-Kaybob belt indicated within Unit "a" becomes more pronounced within Unit "b". Along the flanks of this belt Unit "b" is thicker and entirely sandy, the sandstones are more angular than



elsewhere, non-glaucinitic and non-micaceous, and suggest faster deposition and/or a steeper gradient. One well drilled along the axis of the belt encountered feldspathic sands within Unit "b" (see Map 4).

A progressive change from finer to coarser facies of Unit "c" northwestward may indicate that "c" was a progressively shallower water deposit to the northwest. The clastic source of Unit "c" was probably more distant than that of Unit "a" or "b" because its clastic material is relatively finer. In the Kaybob-Sturgeon Lake belt, on the other hand, a supply of detritus was no longer available; waters in that area were sufficiently shallow, however, for the build up of reefal(?)^{or bank(?)} carbonates. Farther to the west and northwest beyond the reefal belt, shaly, silty, glauconitic and micaceous (back reef?) facies were deposited.

Following Unit "c", muds of Unit "d" covered the entire map area. The detrital source was either more distant or very low, and the "d" shorelines distantly removed from the area.

The "d" shales are interlayered with minor siltstones and carbonates and probably represent a slightly unstable infraneritic environment. Above "d" the sediments change to coarse carbonates and arenites that are typical of an epineritic environment; maroon and green muds common in Units "a" to "d" are almost entirely absent in later units.

The facies of Unit "e", although coarser, generally parallel those of Unit "c". The inflow of sands again concentrated into the central map area and bypassed the carbonate belt of Kaybob-Sturgeon Lake area. However, in the northeast, in place of a shaly "c" basin, a broad shallow bench of coarse "e" carbonates developed. This might indicate the Unit "e" did not extend much beyond its present erosional limits (see Map 7).

The top of Unit "e" is believed to mark the end of Middle Cambrian deposition (p. 24). A minor diastem(?) is indicated locally above the top of "e"

and at the base of "f". Otherwise no major break was observed between these two units. The extrapolated zero-isopach contour of the non-eroded interval from "a" to "d" may give some indication of the mean northward extent of the Middle Cambrian shorelines (see Map 3).

The area available for the study of Unit "f" is small. However the high sand content of "f" suggests an uplift of the source area. The wide lateral spread of the well-sorted sand appears to indicate a prolonged development of a shallow (beach?) facies. A uniform westward increase of grain size points to a possible western source of detritus which might have been the same one that supplied Units "c" and "e" or a new source somewhere in the west. This assumes that the unit is not homotaxial.

Unit "f" was followed by a typical stable sequence of "g" and "h" carbonates grading to minor sandstones and possibly interrupted by diastems (cf. pp. 20 & 21). The source area was apparently again less active.

In summary, it appears that the Cambrian sequence in north-central Alberta prior to Unit "c" was laid down during a slightly unstable transgressive period in an epineritic environment. Unit "d" represents probably a longer interval of quieter, possibly deeper water deposition. It was terminated by an extensive shallowing, a lack of detrital supply and development of "e" carbonates. Unit "e" marked the beginning of a typical stable shelf type of sedimentation which appears to have continued without a major break into the Upper Cambrian. With the exception of "f" (which marked the onset? of the Upper Cambrian) the source remained at low level and supply of detritus was low as indicated by the dominance of carbonates and very subordinate shales. Weak transgressive tendencies remained and are indicated by carbonates which are either sandy or reefal and by dolomitic and limy sandstones.

Some lateral features of Cambrian deposits stand out in the area discussed:

the character of Cambrian units is uniform or broadly gradational; a higher clastic trend is present in the central area of deposition and may be related to a broad Cambrian high in the north-central map area (cf. pp. 26).

Two centres of anomalous deposits are apparent from the data available to date; one is along a belt joining Kaybob and Sturgeon Lake areas, and the other in the vicinity of the Swan Hills area (see Maps 4-7). As the Cambrian well control in the region of the Sturgeon Lake and Kaybob fields is relatively better than elsewhere in the map area the anomalies of this belt can be detailed:

a Proterozoic belt is present there within the Precambrian surface (see p. 8);

Middle Cambrian depositional trends are successively anomalous along the Sturgeon Lake-Kaybob belt (see Maps 4-7);

the pre-Devonian paleogeology illustrates sharp irregularities along that belt (see Map 8).

Basal Devonian facies (see Map 13) and also immediately overlying Devonian beds reflect similar anomalous trends.

If a relationship exists between these observations, it might be explained by a presence of repeatedly active tectonic elements along an axis of tectonic weakness and/or by the rejuvenation of some Precambrian topographic features.

MIDDLE DEVONIAN ELK POINT GROUP

The Middle Devonian Elk Point Group is at a depth of approximately 5000 feet in the northern, 6000 feet in the southeastern, and 10,000 feet in the southwestern map area. It underlies abruptly the basal carbonate of the Beaver-hill Formation (considered by some geologists to be the equivalent of the Middle Devonian Slave Point Formation). It overlies unconformably the Cambrian and the Precambrian in the south and north, respectively. Because of a considerable westward onlap, it ranges in thickness from zero in the west to over 1000 feet in the east-central map area.

In the north, in an area mainly beyond the map boundaries, Law (1955) has divided the Elk Point Group in a descending order into the Watt Mountain Formation, the Muskeg Formation, the Keg River Formation, and the Chinchaga Formation (see p. 5). His terms are not used in this paper, because formational characteristics gradually disappear southward. Instead, in this paper the Elk Point Group is subdivided as follows (cf. Fig. 3):

Watt Mountain Formation	[Upper "zone"
	[Shale "zone"
Clastic and Evaporitic Unit	[Dolomite "zone"
	[Lower "zone"
	[a basal sand, the proposed Assineau Sandstone of this paper
Red Bed Unit	

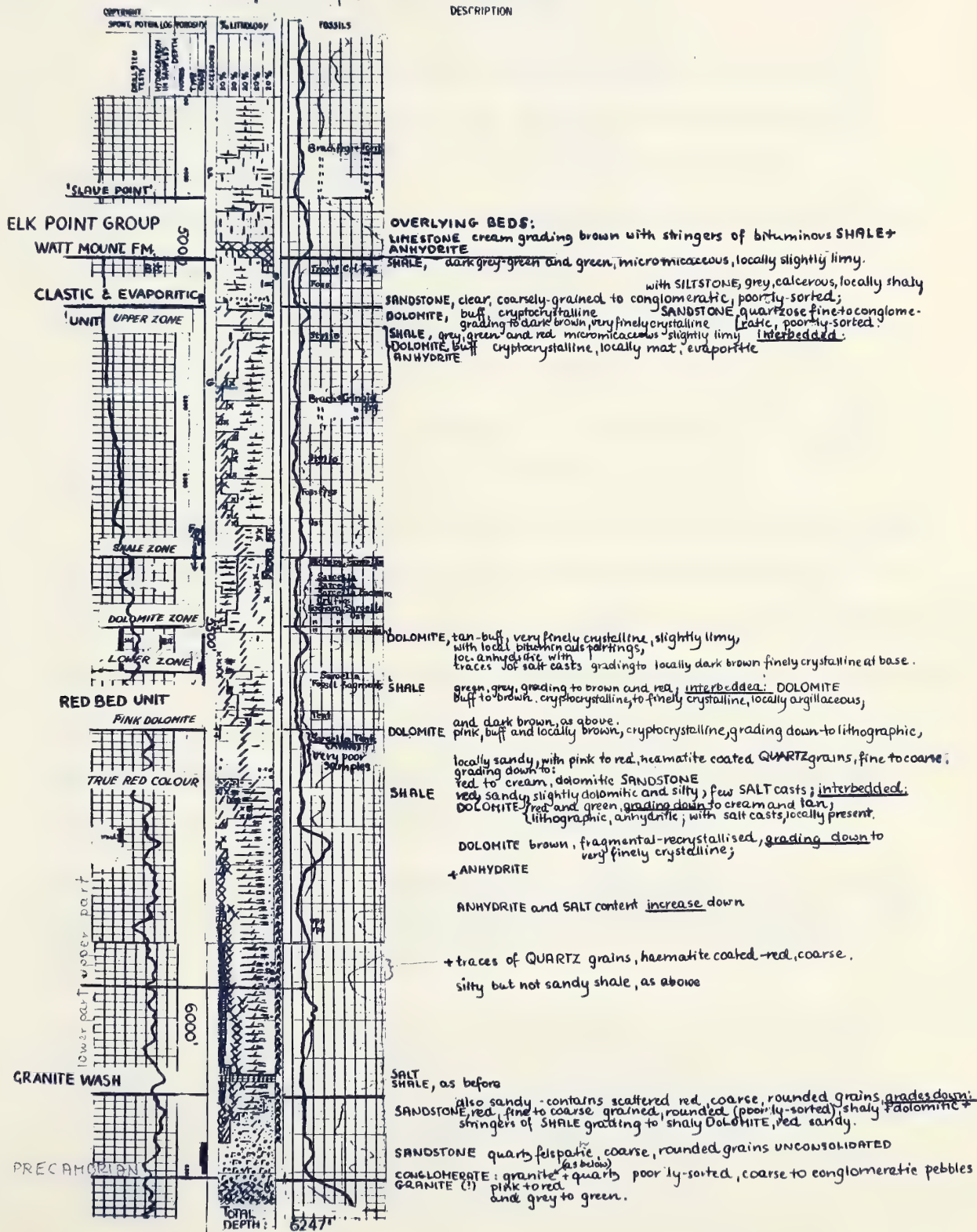
The lowermost of these, the Red Bed Unit, is present only in the easternmost map area.

FIGURE 3

LITHOLOGY LOG - INTERPRETIVE TYPE

LSO 14 sec 30 Twp 72 Rge 2 S 5 W 1 ALBERTA
WELL NAME Union Calalta Mitsue Lk #14-30
SPudded 25.7.56 COMPLETED 10.8.56
K.R. 1931 L.S. 6247' STATES

COPYRIGHT
M. M. SUSKA
CALGARY Tel No.
AMT 7248
AMT 4802
EDMONTON Tel No.
23598



RED BED UNIT

(see Map 9)

The Red Bed Unit of this paper underlies abruptly the basal beds of the Elk Point Clastic and Evaporitic Unit. The top is placed at the top of a characteristic dolomite bed: in the south it is a pink crypto- to finely crystalline dolomite with floating fine sand to pebble sized quartz grains, and has an evaporitic appearance; in the northeast the dolomite grades into a brick-red, argillaceous and anhydritic dolomite. This uppermost dolomite bed is invariably present in the map area although it varies in thickness. (e.g. it is 25 feet at H.B. Virginia Hills No. 1, tp. 65, rge. 6, W. 5th mer., and over 100 feet at Imperial Dapp No. 1, tp. 62, rge. 1, W. 5th mer.).

The uppermost dolomite grades down into a brick-red sequence of interbedded evaporitic and dolomitic shale, shaly dolomite and evaporites (cf. Figs. 3 and 4). The evaporites, mainly anhydrite interbedded with evaporitic carbonates, are more pronounced in the lower part of the sequence, and more so in the east and in the north, where salt is also present, than in the southwest. Laterally the sediments of the Red Bed Unit appear to lap over westwardly. The onlap has a somewhat different character in the north than in the south.

In the north the onlap is not associated with any distinct westward facies change except in a narrow basal zone; e.g. at the Barnsdell West Wabiskaw No. 1 well (tp. 72, rge. 2, W. 5th mer.) and 30 miles east of the truncation lines, the Red Bed Unit is a little over 200 feet thick and contains 100 feet of salt and no arenites.

In the south, however, a broad westward transition from evaporitic facies to evaporites mixed with poorly-sorted clastic material takes place over a broad area prior to the truncation. Thus beyond the east-central map boundaries (e.g. at Imperial Clyde No. 1, l.s. 9, sec. 29, tp. 59, rge. 24 W. 5th mer.), the pink and red sandy dolomite at the top is over 100 feet thick, and the evaporitic sequence below, over 300 feet thick, is mainly salt. Westwardly, i.e. along the eastern map boundaries at Union Calalta Mitsue Lake No. 14-37

LITHOLOGY LOG - INTERPRETIVE TYPE

LOG 10 sec 6 TWP. 82 Red W. 5 MER ALBERTA
 WELL NAME IMPERIAL FUTURITY GODIN LAKE #10-6
 SPUN Feb. 17/57 COMPLETED Mar. 20/57
 LOG 1908' TO 5009' STATUS

COPYRIGHT
 M. M. GUSKA
 CALGARY TEL 465
 AME 7543
 AME 4108
 EDMONTON TEL No.
 25008

DESCRIPTION

ELK POINT GROUP

WAIT MOUNTAIN FORMATION

CLASTIC & EVAPORITIC UNIT

upper zone

MUSKEG EQUIVALENT

shale zone

dolomite

a lower

MUSKEG EQUIV

RED BED UNIT

GRANITE WASH?

PRECAMBRIAN

OVERLYING BEDS

LIMESTONE cream to brown lithographic to subfragmental

SHALE, green calcareous interbedded:
 ANHYDRITE tan to white, finely crystalline, dolomitic, grading
 DOLOMITE and trace of SANDSTONE at base
 ANHYDRITE, white, light grey, tan, mottled and little interbedded
 DOLOMITE +
 SHALE as before.

DOLOMITE, buff very finely crystalline, matt, with ANHYDRITE inclusions

SHALE buff and green, slightly limy, soft, interbedded:
 DOLOMITE, v. light grey, unevenly crystalline, anhydritic, locally grading ANHYDRITE

DOLOMITE light grey, cryptocrystalline to finely crystalline, crystallised, locally grading to LIMESTONE
 SHALE green and bright green-waxy, limy, fairly fissile + ANHYDRITE

LIMESTONE tan, medium to coarse fragmental grading to recrystallised, interbedded
 locally slightly dolomitic, anhydritic and argillaceous
 SHALE green-grey, limy
 locally waxy

SHALE bright green, soft, flaky, very micromicaceous

LIMESTONE light green, very finely crystalline, with scattered fragments, locally slightly argillaceous

DOLOMITE tan, medium recrystallised, sugary, (resat?), calcareous, (translucent)

SHALE olive green, locally waxy, slightly dolomitic, grading to slightly anhydritic

DOLOMITE tan, very finely crystalline

DOLOMITE red, very finely crystalline, grading to SHALE red dolomitic

SHALE green+red slightly limy, mottled Dolomite grey-brown, cryptocrystalline argillaceous

traces of SANDSTONE clear quartz, medium rounded

ANHYDRITE grey, cryptocrystalline to lithographic, interbedded SHALE + SALT as above

SHALE red, micro calcareous, dolomitic, grading to DOLOMITE red, very argillaceous, anhydritic

no samples

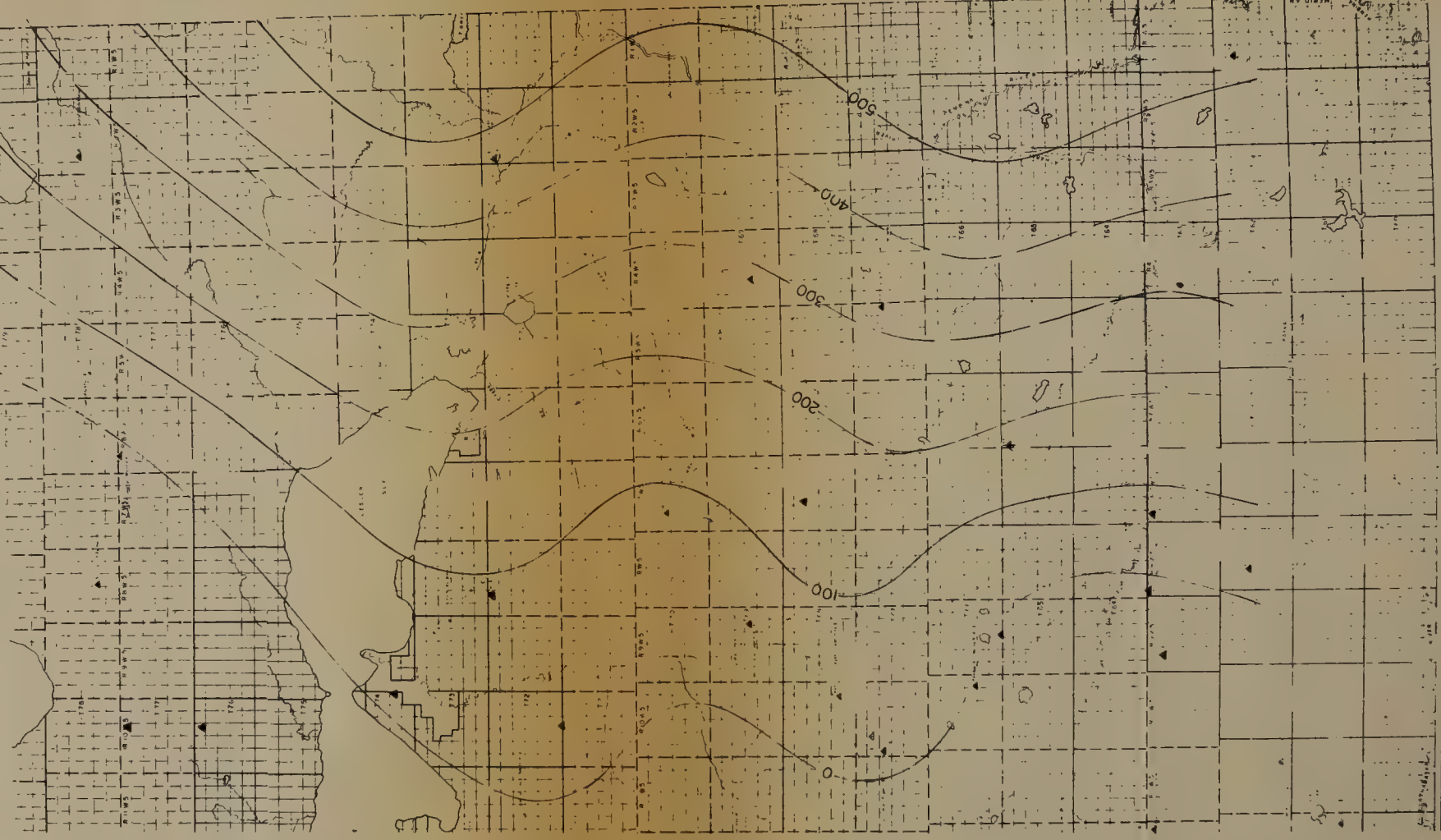
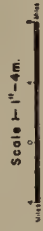
ISOPACHOUS MAP.

10

"RED BEDS"

OF ELK POINT GROUP

NORTH CENTRAL ALBERTA



(tp. 72, rge. 2, W. 5th mer.; see Fig. 3) and Imperial Dapp No. 1 (l.s. 5, sec. 29, tp. 62, rge. 1, W. 5th mer.), both over 64 miles east of the truncation line, the Red Bed Unit contains the pink dolomite about 100 feet thick underlain by over 200 feet of shale, siltstone and fine to medium-grained sandstone, interbedded with evaporites. Further west the Red Bed Unit is thinner still and at Home Imperial Fina Grizzly Mountain No. 6-20 (tp. 70, rge. 7, W. 5th mer.), 15 miles east of the truncation line, the unit consists of the uppermost 30 feet of the crypto-crystalline, pink, sandy dolomite underlain by a red sequence, approximately 60 feet thick, of anhydritic shale interlayered with very fine-grained sandstone and sandy, cryptocrystalline dolomite.

The Red Bed Unit overlies unconformably the Precambrian and the Cambrian in the north and south, respectively. In the south where the uppermost Cambrian beds are sandy, a partly reworked Cambrian sandstone is observed at the base of the Red Bed Unit at most wells.

E.g. at Imperial Dapp No. 1 and at Hudson's Bay East Virginia Hills No. 1 (l.s. 5, sec. 31, tp. 65, rge 6, W. 5th mer.) the uppermost Cambrian "f" sandstone, 100 feet thick, is cream and red in colour, contains anhydrite and evaporitic dolomite throughout and brick-red silt in the upper part.

Locally, where the shaly Red Bed Unit is underlain by the shaly Cambrian, it is difficult to place its lower boundary (e.g. at Home Imperial Fina Grizzly Mountain No. 6-20).

The difference in cuttings between the shales of the Red Bed Unit and those of the Cambrian is their pronounced evaporitic character and a red brick and green colour, as opposed to the maroon and green of the Cambrian. They are commonly dolomitic whereas Cambrian shales are generally non-dolomitic and non-limy (with exceptions). Furthermore, coarse mica and the associated crystals of chloritic matter were not observed in the Red Bed Unit. Trilobite fragments, locally present in Cambrian shales, are absent in the Red Bed Unit.

The isopachous contours of the Red Bed Unit illustrated on Map 9 show a thickening of the Unit from zero in the central map area to over 500 feet in the east. This appears to be a result of progressive eastward addition of lower beds, the uppermost dolomite extending farthest to the west.

ELK POINT CLASTIC AND EVAPORITIC UNIT

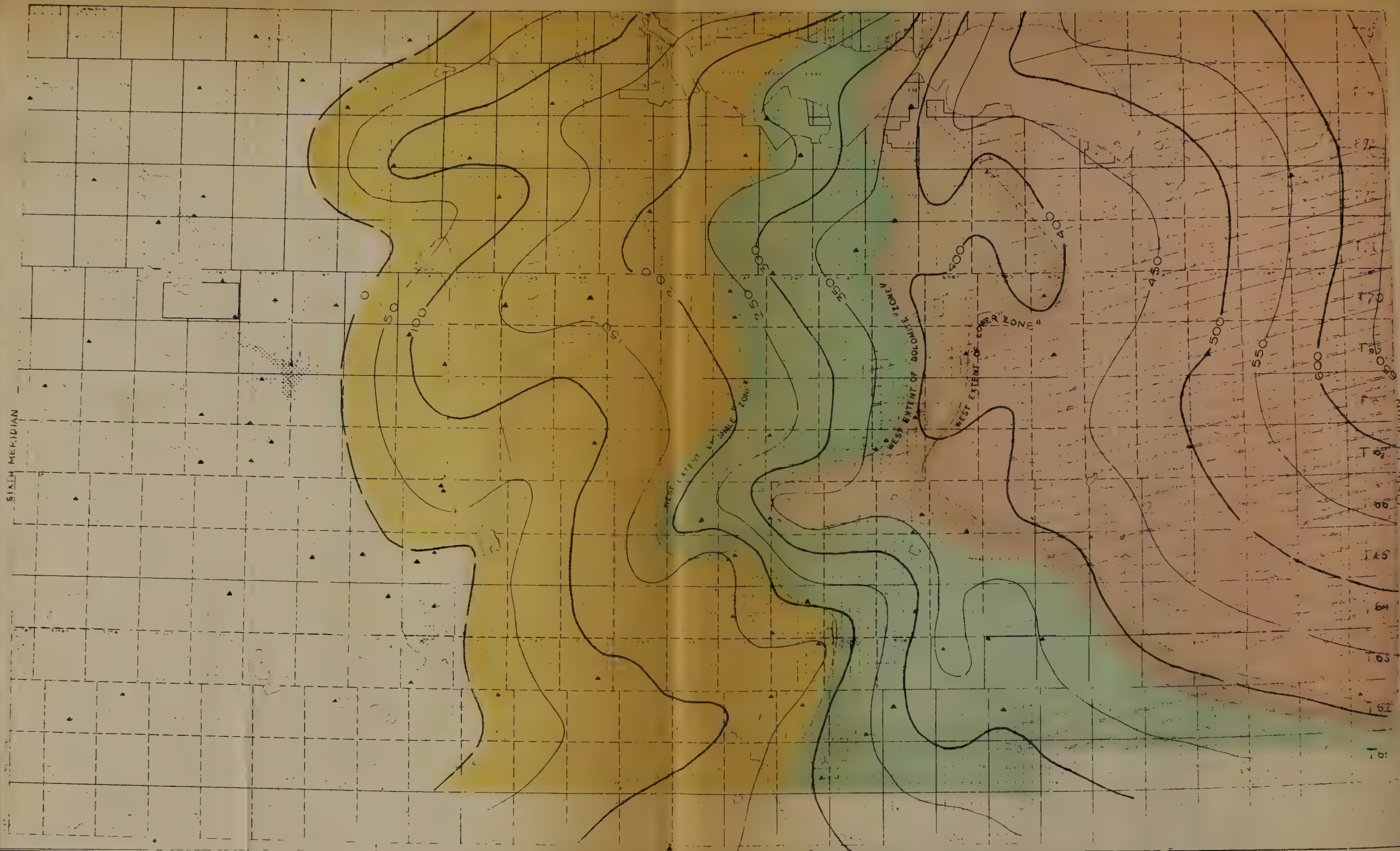
(see Map 10 and Cross-sections A-D)

The Elk Point beds which overlie the Red Bed Unit and underlie the Watt Mountain Formation are referred to in this paper as the Elk Point Clastic and Evaporitic Unit. The Unit underlies the Gilwood Sandstone or the shale of the Watt Mountain Formation abruptly, but without an apparent unconformity. At the top is a persistent bed of anhydrite which grades to anhydritic dolomite and shale in the west-central map area.

The Elk Point Clastic and Evaporitic Unit contains the basal Assineau Sandstone wedge and an overlying sequence of mainly evaporitic and clastic beds. Two persistent "zones" were recognised in the central part of this sequence: the Shale "zone" and the underlying Dolomite "zone". The remaining part of the unit above these zones is referred to as the Upper "zone" and that below as the Lower "zone" (cf. Fig. 3).

As mentioned before, the Clastic and Evaporitic Unit overlaps westwardly and its younger beds extend farther west than the older ones (cf. Figs. 3, 1 and 2, respectively). Thus the thickness of the unit grades from zero in the north-central and southwestern map area to over 800 feet in the northeast and 650 feet in the southeast. The isopachous contours are illustrated on Map 10. The increase of thickness is considerably more abrupt in the northern than in the southern part of the map area.

The Shale "zone" is the most conspicuously fossiliferous bed of the Clastic and Evaporitic Unit. Abundant Eochara and Sarcella sp. are typical and were observed at almost all wells studied where the shale zone is well developed (see p. 42). Crinoid fragments and ostracods are also common within it.



LEGEND

▲ Control wells

— Isopachous Contour of Clastic & Evaporitic Unit

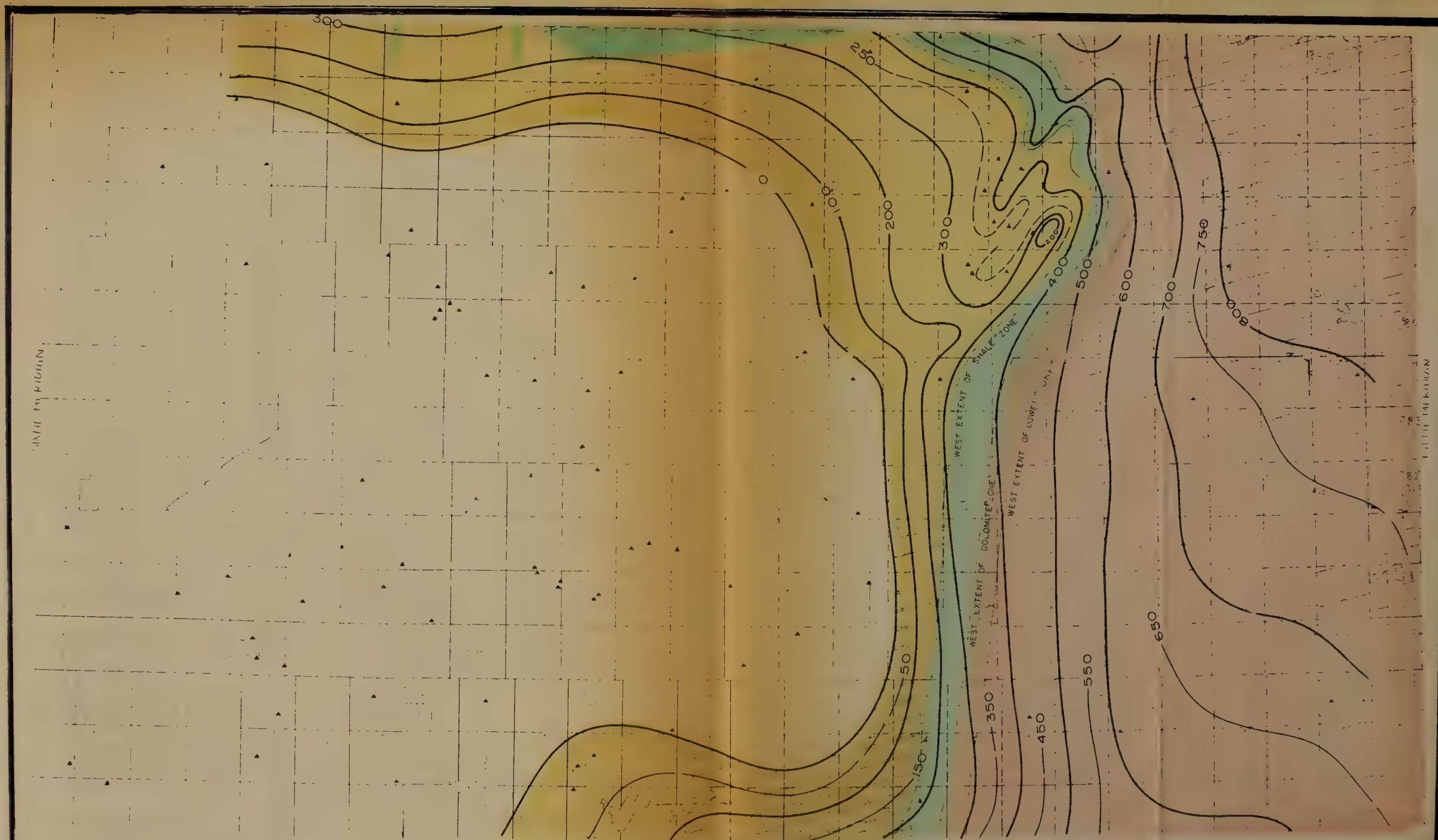
ISOPACHOUS MAP OF CLASTIC & EVAPORITIC UNIT OF ELK POINT GROUP
(INCLUDING ASSINEAU SANDSTONE)

Indicating approximate lateral westward extent of respective zones of the unit

NORTH CENTRAL ALBERTA

SCALE 1:500,000

MAP 10
SOUTH



LEGEND:

▲ Control wells

— 550 — Isomachous Contour of Clastic
Evaporitic Unit

ISOPACHOUS MAP OF CLASTIC - EVAPORITIC UNIT OF ELK POINT GROUP
INCLUDING ASSINEAU SANDSTONE

MAP 1
NORTH

Indicating approximate lateral westward extent of respective zones in the Unit

NORTH - CENTRAL ALBERTA

SCALE - 1 INCH = 12 MILES

Similar fauna, although not as abundant, containing Tentaculites fragments was observed in samples of shale from the Lower "zone" of the Unit at Union Calalta Mitsue Lake No. 14-30 (tp. 72, rge. 2, W. 5th mer.).

The Upper "zone" of the Clastic and Evaporitic Unit is also fossiliferous. Abundant brachiopod and crinoid fragments and ostracods were observed within shaly and dolomitic intervals of that zone. Eochara and Sarcella sp. are locally present, where the evaporitic shales are well developed. Phosphatic (fish?) remains were observed in the central part of the Upper "zone" at Union Red Earth No. 14-17 (tp. 88, rge. 6, W. 5th mer.).

The Dolomite "zone" is usually fossiliferous. Partly recrystallised coral(?), stromatoporoidal and algal structures and also brachiopod fragments and spines were observed in samples from it at several wells, as far south as Imperial Dapp No. 1 (l.s. 5, sec. 29, tp. 62, rge. 1, W. 5th mer.) and as far north as Union Red Earth No. 14-17. Goodman (1956) reported that Dr. C.R. Stelck has recognised a Middle Devonian fauna in core samples of Great Plains Bat Lake No. 6-11 (tp. 84, rge. 5, W. 5th mer.) collected between the depth of 5157-5277 feet, i.e. from an interval corresponding to the lower part of the Dolomite "zone" and/or Lower "zone" of the Clastic and Evaporitic Unit. Dr. Stelck identified the fauna as "a typical Pine Point type of suite of the Ambocoelia meristoides horizon of Middle Devonian".

Generally, although the entire Unit is fairly fossiliferous, fossils are absent in lowermost "zones" in proximity to their southwestern pinchouts (this coincides with the appearance of a brick red colour, which is otherwise not conspicuous in that Unit in the south (cf. Figs. 1 and 2).

A discussion of the lithology and distribution of the respective intervals of the Clastic and Evaporitic Units follows.

Assineau Sandstone

(see Map 11)

The Assineau Sandstone is a name proposed here for a basal sandstone of the Elk Point Clastic and Evaporitic Unit. The name is taken from the Hudson's Bay Union Assineau No. 10-32 (tp. 72, rge. 8, W. 5th mer.) well where the sand is at the depth of 6755 feet and is 90 feet thick.

The Assineau Sandstone overlies abruptly but with no apparent unconformity "the pink dolomite" of the Red Bed Unit in the southeastern part of its area (cf. Fig. 1). It overlies unconformably the Cambrian in the southwest (cf. Fig. 2) and the Precambrian in the northwest.

The sandstone underlies in a westwardly transgressive relationship progressively higher, overlapping beds of the Elk Point Clastic and Evaporitic Unit. The top of the sandstone is placed at the uppermost occurrence of a feldspathic, poorly sorted sand. Generally, the contact with the overlying beds is distinct and gradational over not more than ten feet (e.g. at Home Imperial Fina Grizzly Mountain 6-20-70-7 W.5 and Pan American Morse River #A-1). Locally it is even more abrupt (e.g., at Stanolind House Mountain No. 1, l.s. 7, sec. 29, tp. 70, rge 13, W. 5th mer.).

In the area of its main development (dotted area on Map 1), it is a feldspathic sandstone, which is colourless to pink, grading to a characteristically red colour due to haematite coating of the grains. It is usually poorly sorted, fine grained to conglomeratic, but mainly medium grained to conglomeratic with angular to rounded grains. The larger grains are generally rounded and finer ones more angular. It is slightly dolomitic, locally anhydritic and glauconitic and in the central area of its deposition (see Map 11, and Fig. 1) it is coarser, commonly unconsolidated and extremely porous, repeatedly causing lost circulation upon drilling (e.g., in the Swan Hills field). At one well of the central area, Pan American A-1 Morse River No. 4-13 (tp. 66, rge. 10, W. 5th mer.), a sample collected 90 feet below the top of the Assineau Sandstone, at 9030 feet, contains mainly coal. It is difficult to say if this is due to cavings or not.

ISOPACHOUS & GENERALIZED FACIES MAP OF ASSINEAU SANDSTONE

NORTH-CENTRAL ALBERTA

(indicating lateral gradations and illustrating relationship of underlying beds)

SCALE: 1 inch = 12 miles

5th Meridian

FIG. 110 :

immediately underlying beds:



Mainly felspathic sandstone; porosity developments generally excellent.



Felspathic sandstone & shale interbedded; porosity developments grade from poor to locally good.



Isopachous contour of Assineau Sandstone



Transitional boundary between basal Cambrian sandstones below & Assineau sandstone above; the Assineau sand might be thicker or thinner than indicated.

Control wells



MAP 11



The lateral extent of the Assineau Sandstone is illustrated on Map 11: it shales out gradually in the southeast; it pinches out rather abruptly in the southwest [however it is overlapped there by the silty and sandy facies of the Clastic and Evaporitic Unit and (cf. Fig. 2), as indicated on page 44, its boundary there is arbitrary across a distance of a few miles]; northwestwardly the Assineau is laterally transitional into the younger sands (see Cross-Section B); and in the northeast where it overlies the Precambrian rocks, it may pass into scattered Granite Wash lenses.

In the west-central map area, where the Assineau overlies immediately the Cambrian basal Unit "a" (or "b" and "a" where both comprise a basal sandstone) the lower boundary of the Assineau is difficult to establish. Inadequate control aggravates the problem. Yet the establishment of the boundary would be of stratigraphic importance because different interpretations lead to entirely different, stratigraphic assumptions.

One interpretation is that two thick Cambrian erosional remnants extend northerly one across the Big Prairie Settlement and the other across H.B. Union Valleyview No. 1 (l.s. 15, sec. 20, tp. 74, rge. 1, W. 5th mer.) and the Assineau is thin or absent (as assumed by the writer in case of the Valleyview area and so indicated on Maps 1, 2 and 10). Another possibility of an entirely different stratigraphic interpretation is that a very abrupt Cambrian erosional pinch-out was present at these localities and the area subsequently had an abnormally thick Assineau Sandstone deposited; still another possibility (assumed by the writer in the case of the Big Prairie trend and so indicated on the maps) is that the areas represent originally thick Cambrian remnants, which during the Assineau transgression were partly reworked, and especially so in the upper portion, which the writer considers to be Assineau.

The conclusions arrived at by the writer are based partly on the extrapolation of the isopachs (since the control is inadequate) of the unquestionably Cambrian beds northward, and mainly on rather meager and inconsistent lithologic differences, observed between the basal Cambrian sandstone and the Assineau. These differences are summarised below. Both sands are generally poorly to fairly well sorted and both contain glauconite.

Assineau Sandstone:	Basal Cambrian sandstone:
Sand grains are typically maroon-hematite coated	Sand grains are mainly clear, scattered hematite coating present
Roundness tends to increase with depth	Roundness tend to decrease with depth, if feldspathic
Feldspar is abundant	Feldspar absent or present
Shale, if present, is mainly light green and brick red; it is mainly soft; if it is red it is anhydritic and dolomitic, non-micaceous	Shale is mainly darker green and maroon, hard and splintery, commonly silty, commonly coarsely micaceous and also finely micaceous, rarely green and bright green

It is evident that the criteria available to, and used by the writer are not always adequate and thus the possibility of different interpretations of the boundary between the basal Elk Point sandstone and the basal Cambrian sandstone should be borne in mind when evaluating the accompanying maps (Maps 2, 8, 10 & 11).

Lower "Zone" of Clastic and Evaporitic Unit

The lateral extent of the Lower "zone" of the Clastic and Evaporitic Unit is indicated on Map 10.

In the south it overlies sharply the pink dolomite of the Red Bed Unit (cf. Fig. 3) with an Assineau wedge in between in the west. In the north it overlies scattered Granite Wash lenses and/or the Precambrian rocks.

The boundary with the overlying Dolomite "zone" is sharp in the south (cf. Fig. 3). In the north where carbonates in the Lower "zone" predominate, the boundary is not apparent and the Lower "zone" and the overlying Dolomite "zone" there form the Keg River Formation (Law, 1955, cf. p. 5).

The lithology of the Lower "zone" is chiefly green, limy and dolomitic shale with minor carbonates. In the southeast where it grades laterally westwards and vertically down into the Assineau (cf. p. 39) red shales are

locally present. In the north-central area evaporites and carbonates prevail and local stringers of finely to medium crystalline sucrose dolomite with good porosity developments are present.

The thickness of the Lower "zone" grades from zero (tentatively indicated on Map 10) to over 75 feet in the southeastern and east-central area. In the north-east the combined thickness of the Lower "zone" and the overlying Dolomite "zone", i.e., that of the Keg River Formation, is over 200 feet.

Dolomite "Zone" of Clastic and Evaporitic Unit

The eastern depositional edge of the Dolomite "zone" of the Clastic and Evaporitic Unit is indicated on Map 10. Beyond, it is lapped over by the Shale "zone". The boundary with the overlying Shale "zone" is sharp.

It is underlain by the Lower "zone" of the Clastic and Evaporitic Unit in the east, whereas westwardly, beyond the depositional limit of the Lower "zone" the Dolomite "zone" overlies the Assineau Sandstone in the south and scattered Granite Wash lenses and/or Precambrian strata in the north.

The Dolomite "zone" in the east-central and southeastern area is comprised of white to brown, slightly anhydritic, fine to medium crystalline, locally sucrose dolomite and limestone with dolomitic rhombs (cf. Figs. 3 and 4). Reefal developments up to 20 feet thick are common; they are indicated by a medium to coarsely crystalline and sugary texture, similar to the upper Devonian D-2 dolomite of Central Alberta, and contain locally fair to good intergranular and vug porosity (e.g., at Imperial Dapp No. 1, l.s. 5, sec. 29, tp. 52, rge. 1, W. 5th mer., Pan American Parker Lake No. 4-16-69-4 W. 5th mer., and Imperial Futurity Godin Lake No. 19-6, tp. 82, rge. 1 W. 5th mer., illustrated on Fig. 4).

In the southern map area, the dolomite zone grades westward into a very finely and finely crystalline and argillaceous dolomite (e.g., at Home Imperial Fina Grizzly Mountain^{No. 6-20}, l.s. 6, sec. 20, tp. 70, rge. 7, W. 5th mer.), and farther westward, that is, close to its pinch-out it grades into a sandy dolomite.

In the northernmost map area the lower boundary of the Dolomite "zone" is indistinguishable because, as mentioned previously, it merges there with the underlying carbonate beds of the Lower "zone" of the Clastic and Evaporitic Unit. (e.g., at Shell Maria Lake No. 1, l.s. 2, sec. 28, tp. 86, rge. 4, W. 5th mer.).

The Dolomite "zone" thickens from zero (tentatively indicated on Map 10 to over 60 feet in the southeast and to over 100 feet farther east, beyond the map boundaries. In the northeast, the carbonate sequence, comprising both the Lower "zone" and the Dolomite "zone" is over 200 feet thick.

Shale "Zone" of Clastic and Evaporitic Unit

The lateral extent of the Shale "zone" is indicated on Map 10.

The contact with the overlying beds is gradational; it is placed at the top of a distinctive clastic, mainly shaly section below the Upper "zone" of the Clastic and Evaporitic Unit. In the east, the Shale "zone" overlies the Dolomite "zone". In the southwest and northwest, respectively, it overlies the Assineau Sandstone and the Granite Wash and/or the Precambrian.

In the northern wells it is a green to red and locally maroon, limy shale, interbedded with minor layers of evaporitic dolomite and anhydrite (e.g., at Great Plains Triad Bat Lake No. 6-11, tp. 34, rge. 5, W. 5th). In the south and south-east it is a green, greenish grey, limy and anhydritic shale, interbedded locally with evaporitic limestone, dolomite and anhydrite (e.g., at Home Imp. Fina Grizzly Mountain No. 6-20, tp. 70, rge. 7, W. 5th mer., and Union Calalta Mitsue Lake

No. 14-30, tp. 72, rge. 2, W. 5th mer., illustrated on Fig. 3). As mentioned previously, at almost all wells in the area (cf. exceptions below) the writer observed abundant chara: Sarcella sp. and Eochara sp. in the Shale "zone".

In the south a broad, lateral facies change occurs within the Shale "zone" in the vicinity of its depositional limit: its lower part grades southwestwardly into reddish, shaly, dolomitic, locally anhydritic, poorly-sorted, unfossiliferous quartz sandstone; farther west, along the truncation line of the "zone", excellent porosity developments are present in this sandstone and the Shale "zone" grades down into the underlying Assineau Sandstone (e.g. at Virginia Hills No. 16-12, tp. 66, rge. 13, W. 5th mer., Swan Hills 8-11, tp. 68, rge. 10, W. 5th mer. and Edith Lake No. 11-19, tp. 67, rge. 10, W. 5th mer.; see Fig. 1 and p. 39).

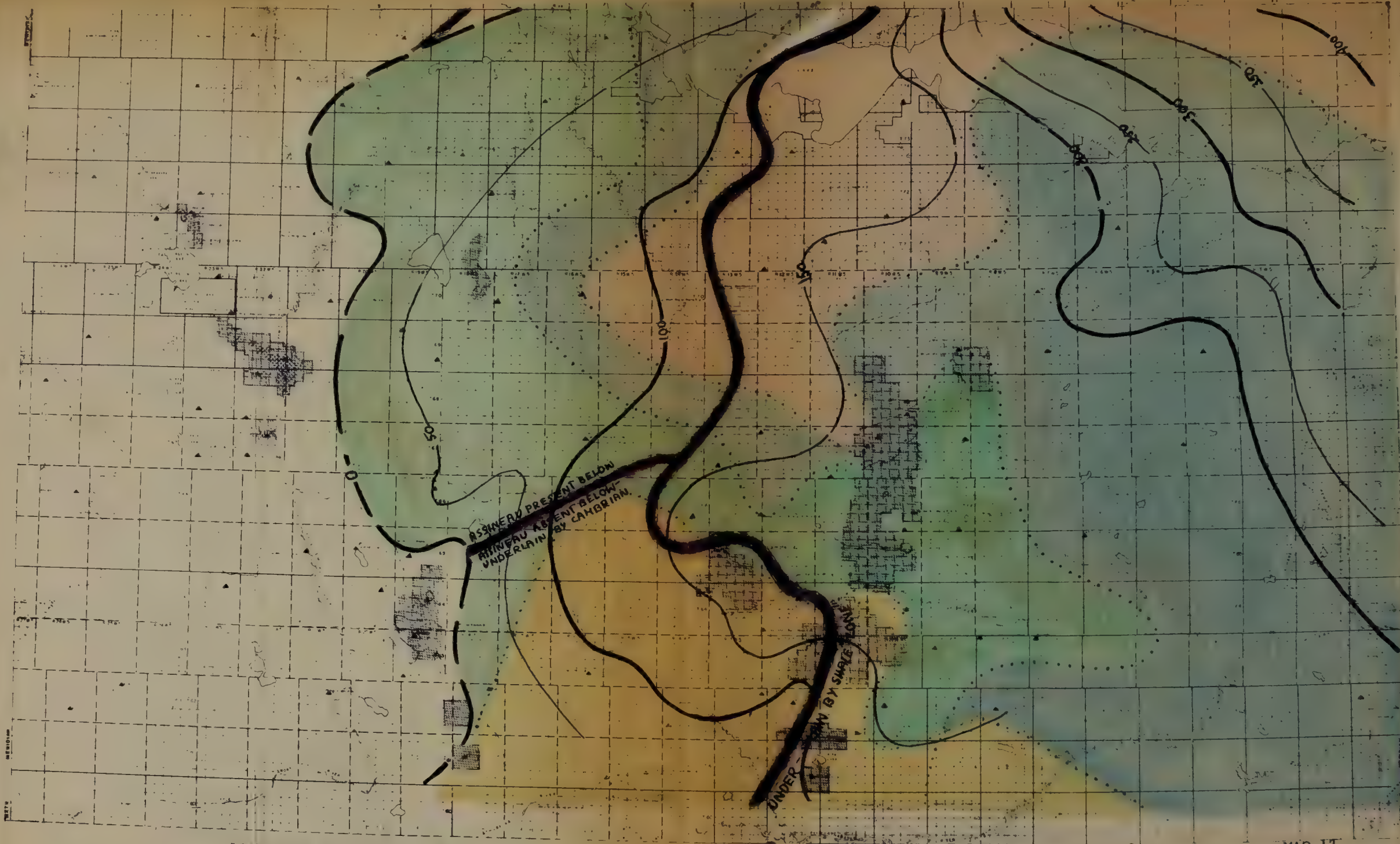
In the north the Shale "zone" pinches out westerly without any pronounced facies change being apparent.

The thickness of the Shale "zone" in north-central Alberta is between 40 and 100 feet. It thickens somewhat towards the Peace River "high" at the expense of the overlying beds, before it finally pinches out.

Upper "Zone" of Clastic and Evaporitic Unit

(cf. Maps 1, 10 and 12)

The eastern depositional edge of the Upper "zone" of the Clastic and Evaporitic Unit is indicated on Map 10. In the east it overlies the Shale "zone"; in the west (brown area on Map 10) it overlaps it and in the southwest the Upper "zone" overlies the basal Assineau sand and in the northwest the Granite Wash and/or the Precambrian (see Map 12).



ISOPACHOUS AND GENERALIZED FACIES MAP OF UPPER "ZONE" OF CLASTIC AND EVAPORITIC UNITS OF ELK POINT

NORTH CENTRAL ALBERTA

MAP 12

W. B. SWIFT

MAP 17

ISOPACHOUS AND GENERALIZED FACIES MAP OF UPPER "ZONE" OF CLASTIC AND EVAPORITIC PART OF ALBERTA GROUP

NORTH-CENTRAL ALBERTA

scale: 1 inch 12 miles



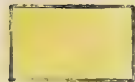
Evaporites > 60%
mainly anhydrite and salt with some
evaporitic dolomite and shale.



60% > Evaporites > 30%
limy and dolomitic shale interbedded
with little anhydrite and evaporitic
carbonates and minor salt.



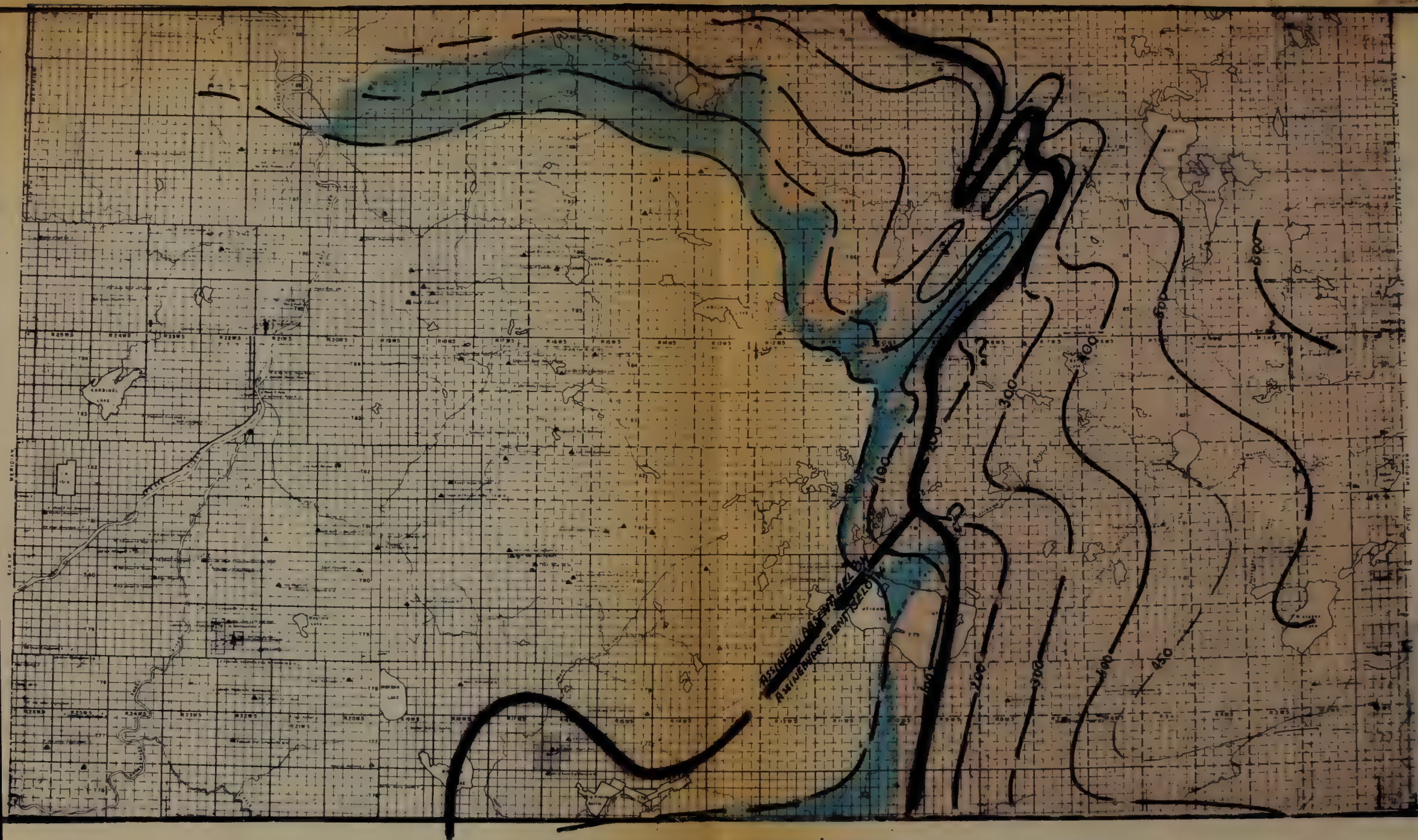
Evaporites > 30% Sandstone < 30%
predominantly shale, interbedded with
little anhydrite, evaporitic carbona-
tes and minor salt.



Sandstone > 30%
mainly sandy and silty shale and silty
and shaly sandstone.

-300-

Isopachous contour of Upper "zone".



ISOPACHOUS AND GENERALIZED FACIES MAP OF UPPER "ZONE" OF CLASTIC AND EVAPORITIC UNIT OF ELK POINT GROUP

NORTH-CENTRAL ALBERTA

scale 1 inch = 12 miles.

MAP 12
NORTH SHEET

The Upper "zone" underlies the Watt Mountain Formation without an apparent unconformity, as indicated by a persistent top bed of anhydrite and/or anhydritic dolomite (cf. Figs. 1, 3 and 4). The high resistivity of this bed and its high self-potential values are easily recognised on the electric logs (in the west-central corner of the area the bed is shaly but the electric log character, although not as pronounced, is similar; cf. Fig. 2).

It might be noted that, in general, the relationship between this uppermost bed of the Clastic and Evaporitic Unit and the overlying Gilwood Sandstone is similar to that between the uppermost, pink dolomite of the Red Bed Unit and the overlying Assineau Sandstone, although the pink dolomite varies more in thickness.

The lithology of the Upper "zone" of the Clastic and Evaporitic Unit changes considerably across the area discussed. Its generalised facies are indicated on Map 12.

In most of the eastern part of the southern map area (blue or lined area on Map 12) the "zone" has a characteristically "dull", light coloured, evaporitic appearance in the samples and rather a varied content of the following: shale which is mainly green to grey; dolomite which is light buff and locally grey, crypto- to very finely crystalline with "chalky" appearance; less commonly, tan uniformly crypto-crystalline limestone; and white and buff finely crystalline anhydrite. The red colour is conspicuously absent except for a rare 10 feet of red siltstone or fine sandstone and shale (cf. Fig. 3). The anhydrite content increases eastwardly.

In the southwest, closer to the truncation line of the "zone" a similar grey sequence occurs in the upper part. The lower beds, on the other hand, contain cream to red, highly dolomitic and shaly siltstone, grading to shale and carbonates with stringers of conglomeratic quartz grains.

Farther to the southwest (yellow or dotted area of the map) the sandy content of these lower beds increases and they are transitional into the underlying Assineau Sandstone (cf. Fig. 2); they could be, perhaps, alternatively regarded there as an argillaceous and dolomitic equivalent of the Assineau (which according to the present correlation is conspicuously absent or thin in that area -- as indicated on Map 11).

In the northern and north-central area extending into a southerly "tongue", the Upper "zone" comprises chiefly evaporites (cf. Fig. 4 and see pink area of Map 12). The lithology there is: tan to buff, cryptocrystalline to finely crystalline, evaporitic carbonates, interbedded with anhydrite and little dolomitic limy shale. "Floating" sand grains up to conglomeratic size are present where the Unit immediately overlies the Assineau Sandstone (e.g. at Stanolind House Mountain No. 1, l.s. 7, sec. 29, tp. 70, rge. 13, W. 5th mer. and Imperial Jossard No. 1, l.s. 11, sec. 11, tp. 73, rge. 13, W. 5th mer.).

Farther to the north and east (within the pink area of Map 12) the "zone" becomes predominantly finely crystalline anhydrite with some salt and minor stringers of shale and dolomite; still farther to the northeast, beyond the map boundaries, salt becomes prominent.

In the northwest, the evaporitic facies of the Upper "zone" appear to extend into the very proximity of the truncation line and a facies change to more clastic sediments, such as in the southwest, was not observed.

The thickness of the Upper "zone" grades from zero in the west to 585 feet in the northeast. The isopachous contours of the Upper "zone" (and so also these of the entire Clastic and Evaporitic Unit) divide the map area into two main regions (cf. Maps 10 and 12) the south and the north.

In the south, a very gradual thickening of three to six feet to a mile of the Upper "zone" parallels a gradual eastward addition of the lower beds across the yellow area of Map 11, i.e. in the area of the immediate lap of the Upper "zone"; to the east of the yellow area the thickness of the Upper "zone" is almost constant.

In the north, a more spectacular increase of thickness of nearly 20 feet to a mile is indicated across the area of the immediate lap; to the east of it, where other beds of the Clastic and Evaporitic Unit underlie it, the Upper "zone", nevertheless, thickens markedly, some 10 feet to a mile, on the average.

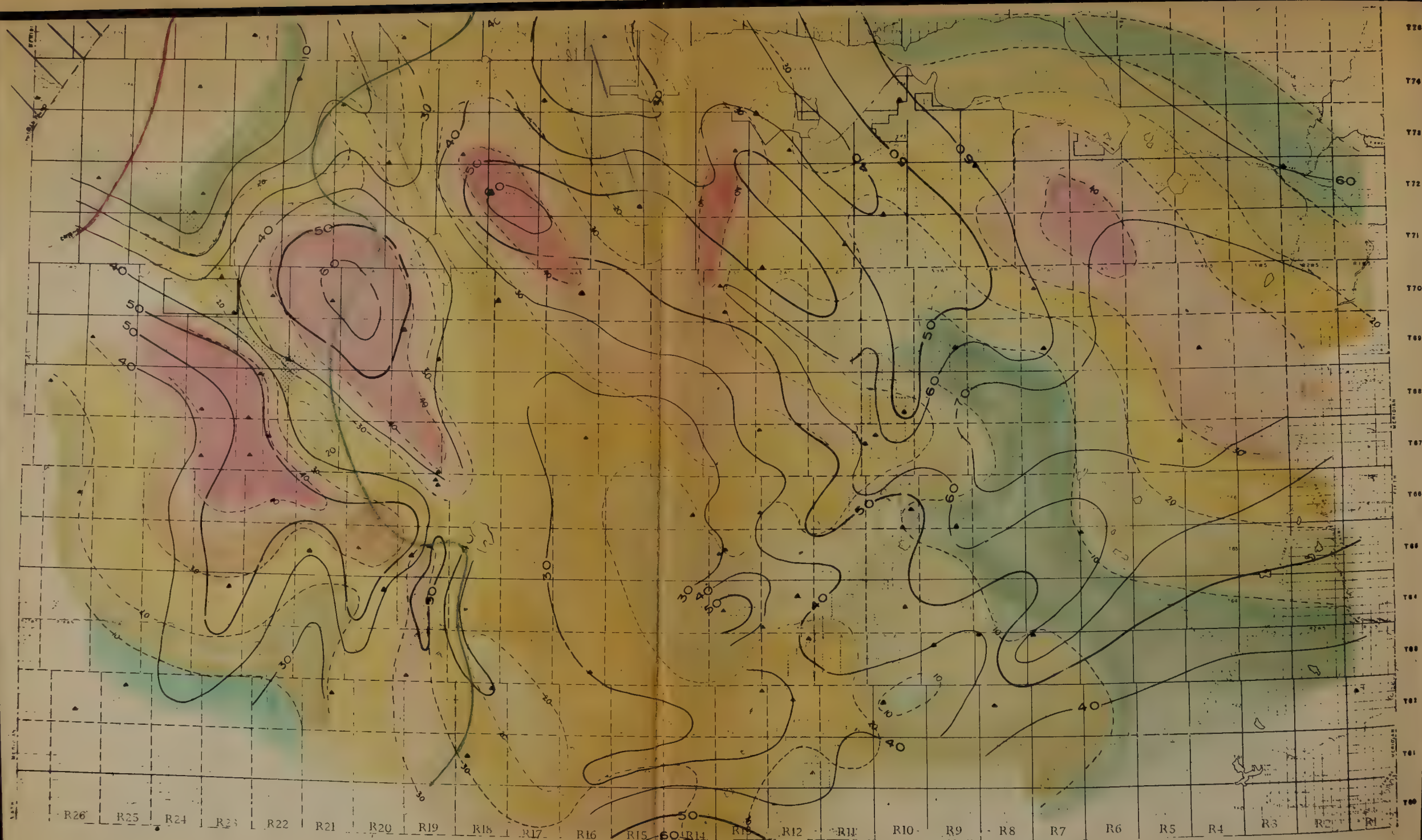
WATT MOUNTAIN FORMATION AND YOUNGER

(see Map 13)

Watt Mountain Formation of northwestern Alberta was described by Law in 1955 (cf. p. 5). It overlies there the Muskeg Formation of the Elk Point Group and underlies the Slave Point Formation. Conditions similar to those described by Law are present in the eastern area of this study where the Watt Mountain overlies the Clastic and Evaporitic Unit; westwardly, however, an Elk Point onlap takes place and beyond the zero isopach of the Clastic and Evaporitic Unit the Watt Mountain Formation overlies directly the Precambrian in the north and the Cambrian in the south.

The western pinch-out of the true Watt Mountain Formation might be expected to parallel closely the pinch-out of the Clastic and Evaporitic Unit in the west. However, the Watt Mountain Formation consists of clastic beds, i.e., sandstones and shales: therefore where it directly overlies Precambrian strata it coincides with the basal Paleozoic clastic beds, i.e. the Granite Wash; whereas where it





REGIONAL ISOPACHOUS MAP OF WATT MOUNTAIN FORMATION AND YOUNGER

NORTH-CENTRAL ALBERTA

Scale line 12 miles

MAP 13
SOUTH SHEET

MAP 13
REGIONAL ISOPACHOUS MAP OF WATT MOUNTAIN
FORMATION AND YOUNGER

Indicating tentatively Gilwood sand developments

NORTH-CENTRAL ALBERTA

Scale 1 inch = 12 miles

LEGEND

Control Wells

_____ 40 _____ Isopachous contour of Watt Mountain Formation and younger
- - - - - Colour boundaries

GILWOOD SANDSTONE OR NET SAND CONTENT:

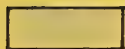
SOUTH SHEET AREA:

	absent
	0-10 feet
	10-20 feet
	20-30 feet
	30-40 feet
	40-60 feet

NORTH SHEET AREA:

	absent
	0-10 feet
	10-20 feet
	20-40 feet
	40-60 feet

sand grains present in shale



Basal Clastic Interval of "Watt Mountain Formation and/or Younger" absent.



Possible axes of underlying "highs".



Beaverhill Formation absent (approximate).



Approximate west extent of the underlying Elk Point Clastic and Evaporitic Unit.

To the east the contours represent the true Watt Mountain Formation.

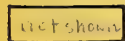
To the west the contours represent Watt Mountain Formation and younger.



Approximate north extent of the Cambrian strata immediately below.

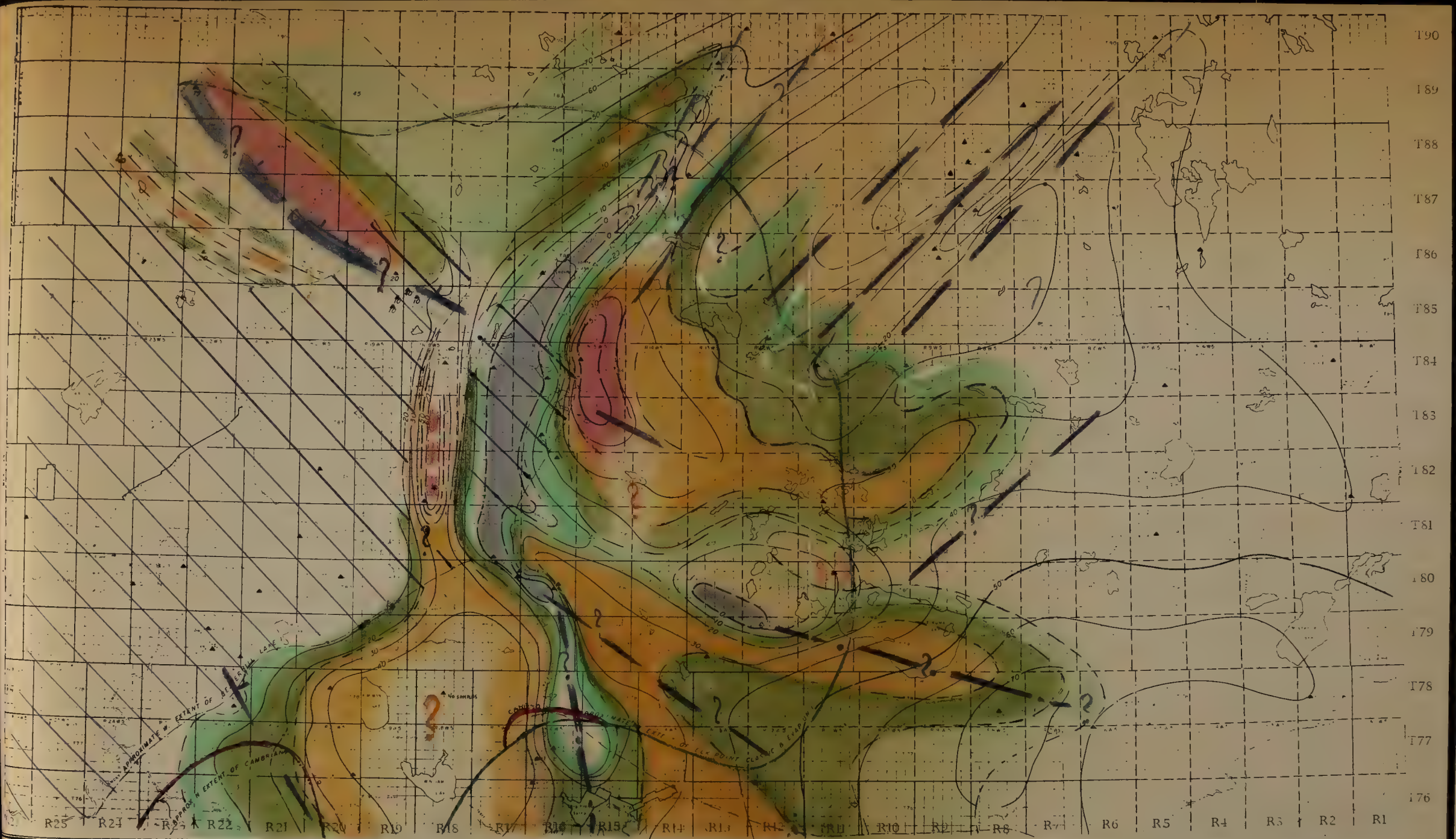
To the north, Gilwood is the basal Palaeozoic bed and merges with the Granite Wash.

To the south, Gilwood is the basal Devonian sand and may contain reworked Cambrian sediments.



Marginal Area:

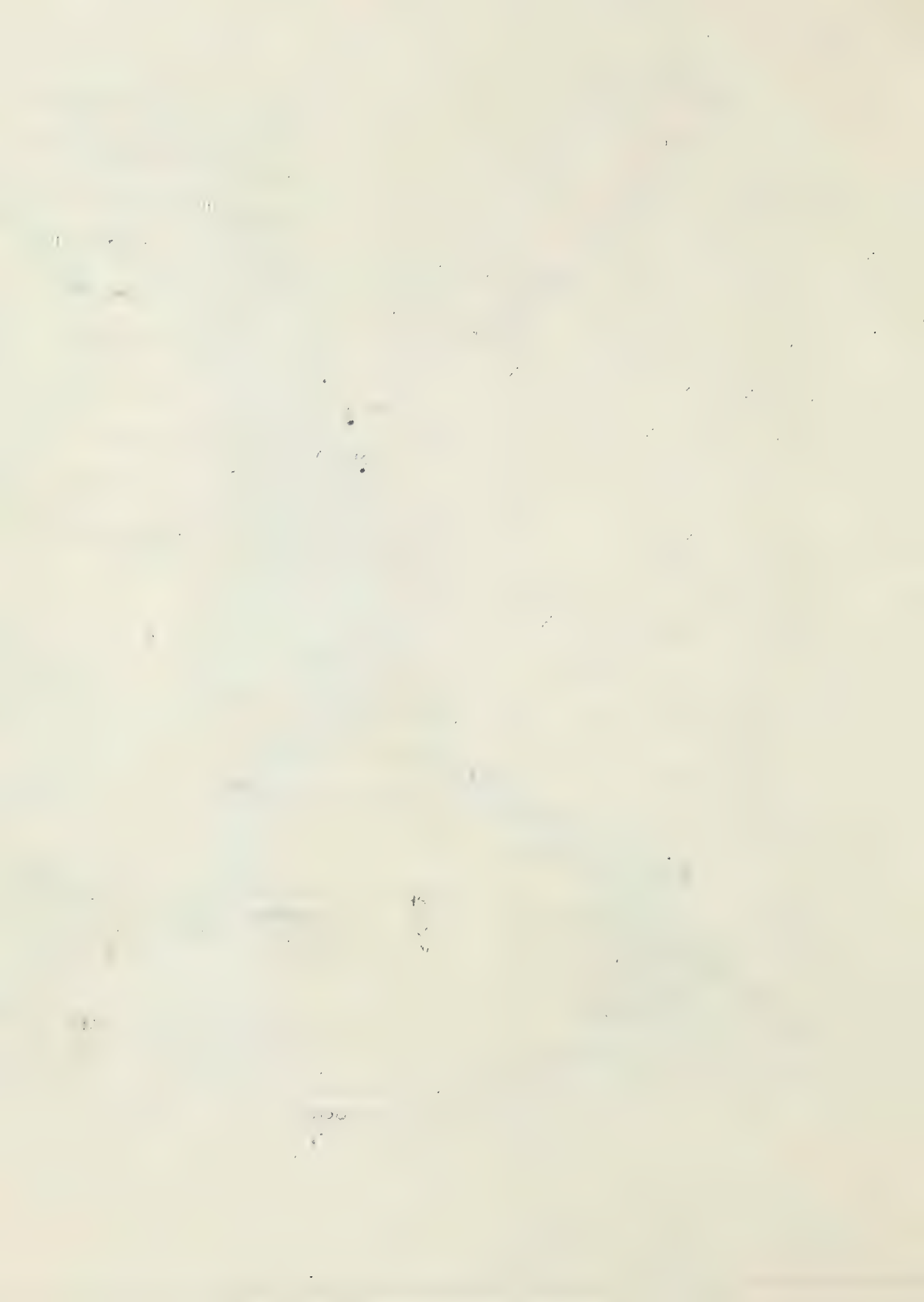
Contacts between Gilwood sandstone, Assinieu sandstone and basal Cambrian sands are arbitrary and transitional. (Porous connection is probably present.)



REGIONAL ISOPACHOUS MAP OF WATT MOUNTAIN FORMATION AND YOUNGER
NORTH-CENTRAL ALBERTA

Scale line: 12 miles

MAP 13
NORTH SHEET



directly overlies the Cambrian sediments, it coincides with the basal Devonian clastic beds. It is hardly possible, therefore, to find the line where (and if) these basal clastics become of younger age than Watt Mountain. Therefore, the writer mapped the interval referred to as "Watt Mountain Formation and younger" as far westward as the Beaverhill Formation is present above it. This interval comprises the true Watt Mountain Formation where underlain by the Clastic and Evaporitic Unit and overlain by the basal carbonate of the Beaverhill Formation (or the Slave Point Formation?). It is probably a diachronic interval, younger westward beyond the westward limits of the underlying Clastic and Evaporitic Unit.

As mentioned, the interval consists almost entirely of detrital material. An isopachous map of the interval which illustrates also the net sand isopachs, is enclosed (Map 13).

In the northeast and in the southeastern corner of the map area, the Watt Mountain Formation is a uniform bed of locally limy, locally anhydritic, green, grey-green, grey and purple shale. Westwardly in the north, in the proximity of the Watt Mountain onlap, floating quartz grains were observed at a few localities in the shale (e.g., at California Standard Utikuma River No. 16-27, tp. 80, rge. 11, W. 5th mer.; cf. Figs. 3 and 4).

In the northwest and in the major part of the southern map area, the interval referred to as the Watt Mountain Formation and younger, contains sandy facies referred to as the Gilwood Sandstone (cf. p. 5). It is a poorly sorted, fine to conglomeratic, quartz sandstone with fine grains more angular than coarser ones; it is quartzitic, locally limy and commonly glauconitic and feldspathic (cf. Figs. 1 and 2).

Fresh, salmon coloured and pink feldspar was observed in the sandstone as far south and east as Socony Utikuma No. 1 (l.s. 12, sec. 10, tp. 78, rge. 8, W. 5th mer.) and Pan American Parker Lake No. 4-16 (tp. 69, rge. 4, W. 5th mer.).

Close to the southeastern and possibly also southwestern (where the control is inadequate) pinch-out of the Gilwood facies, and also locally in the northwest in the upper portion of the Gilwood Member, the Sandstone is finer, locally glauconitic and argillaceous. Intercrystalline porosity developments in the Gilwood sandstone are generally excellent.

A marked difference in the distribution of the sandy facies of the interval referred to as the "Watt Mountain Formation and younger" may be observed between the northern and the southern parts of the map area (see Map 13). In the north the

line of the eastern sand pinch-out corresponds roughly to the western boundary of the underlying Elk Point sediments, whereas in the south the sandstone pinch-out extends far beyond that boundary; i.e., in the north the sandstone facies is developed only in the west where the unit coincides with the Granite Wash, whereas beyond the lap in the east the true Watt Mountain Formation is mainly shale; in the south the sandy Gilwood facies extends far eastwardly into the true Watt Mountain Formation.

Furthermore, in the southern part of the area, on a regional scale, the feldspar content and the average size of grains increase toward the north-central area and the argillaceous content of the Gilwood sand increases regionally to the southwest and to the southeast. In the northern part of the area the distribution of the poorly-sorted and fine-grained sands and the distribution of the feldspathic, argillaceous and anhydritic content has a local, irregular character, typical of the Granite Wash of northwestern Alberta.

The isopachous contours of the interval discussed are illustrated on Map 13. The thickness of the interval grades from zero to over 100 feet. These gradations are abrupt in the north where the interval overlies the Elk Point Group and more so where it overlies the Precambrian, and are gentle in the south where the interval overlies the Cambrian.

In the north, e.g., in the Red Earth Creek area, the isopachous contours of the interval probably reflect a rugged underlying Precambrian topography (in spite of the fact that a thickness of Clastic and Evaporitic Unit is in between). In the northwest where the Gilwood and Granite Wash coincide the variations in thickness are even more abrupt:

For example, one could speculate that a downthrown side of a fault is following a line joining Union Deadwood No. 1 (tp. 89, rge. 22, W. 5th mer.) and Shell Runaway Lake No. 1 (tp. 86, rge. 20, W. 5th mer.). The Gilwood interval there is about 100 feet thick, sandy, shaly and anhydritic, and without feldspar; immediately to the southwest of the line, on the upthrown side of the fault(?) the interval is absent at Evans H.B. Union Peace River No. 6-13 (tp. 88, rge. 22, W. 5th mer.), and it is 10 feet thick, sandy and feldspathic in the Three Creeks area (tp. 85, rges. 18 and 19, W. 5th mer.).

In the south the outline of the isopachous contours of the Watt Mountain and younger interval and also the distribution of its sandy facies, follow more gentle trends. Regionally they appear to be a prolongation of the major trends of the northern area.

Fossils are not common in the Watt Mountain Formation (and appear to be absent where the brick red coloration is conspicuous). Crinoid and brachiopod fragments were observed in samples from several wells of the area discussed. Chara were observed at Stanolind Loon River No. 1 (l.s. 16, sec. 23, tp. 90, rge. 11, W. 5th mer.) and at Imperial Dapp No. 1 (l.s. 5, sec. 29, tp. 62, rge. 1, W. 5th mer.) and Trochiliscus (?) sp. at Union Calalta Mitsue Lake No. 14-30 (tp. 72, rge. 2, W. 5th mer.).

Guthrie (1956) reports several ostracods and fish scales in a core of Gilwood Sandstone taken at 10,103 feet from Stanolind Giroux Lake No. 1 (l.s. 6, sec. 20, tp. 65, rge. 20, W. 5th mer.); his tentative identification suggests Middle Devonian affinity of the ostracodes and he compares the fish scales to those of Acanthodes of the Devonian age. The same writer reports also fish scales, ostracod molds and plant fragments from the Gilwood Member at Great Plains Triad Muskeg No. 1-9 (tp. 73, rge. 18, W. 5th mer.). A Middle Devonian fauna was also reportedly collected from cores of the Gilwood Sandstone of Stanolind House Mountain No. 1 well (l.s. 7, sec. 29, tp. 70, rge. 13 W. 5th mer.) (personal communication from the geological staff of Pan American Oil Co., 1958).

CORRELATION OF MIDDLE DEVONIAN BEDS

The Elk Point sequence of the area discussed provides continuous lithological correlation between two Elk Point sections, that of central Alberta, described by Crickmay (1954) and McGehee (1959) and that of northwestern Alberta, described by Law (1955).

The Watt Mountain Formation of Law extended into the area of this paper corresponds to Crickmay's Member 1 of the Elk Point Group. At Anglo Canadian Elk Point No. 11 (l.s. 2-21-57-5 W4, 120 miles south and east of the area) it is 65 feet thick and consists of red and green shale and interbedded dolomite.

The Clastic and Evaporitic Unit of this paper corresponds to Crickmay's members 2 and 3, and is over 700 feet thick in the Elk Point area (as compared to 650 feet and over 800 feet in the southeastern and northeastern areas of this thesis, respectively). The lithological "zones" of the unit may be traced eastward from north-central Alberta to Crickmay's type area.

The Upper "zone" corresponds to Crickmay's Member 2 and to the "First salt" of McGehee and is approximately 500 feet thick in the Elk Point area (as compared to 400 feet and to 600 feet in the southeastern and in the northeastern thesis area. The maximum development of the zone to the east of the thesis area is close to 700 feet).

The Shale "zone" that thins easterly from north-central Alberta corresponds to the uppermost shaly 15 feet of Crickmay's Member 3 at Anglo Canadian Elk Point No. 11.

The Dolomite "zone" corresponds to the interval, referred to as the Stromatoporoid-coral-algal zone by Belyea (1952) to the east and southeast of the thesis area where it is over 100 feet thick. Farther to the east in the Elk Point No. 11 well the zone constitutes the middle 40 feet of carbonates within Crickmay's Member 3.

The Lower "zone" thickens slightly to the east of the thesis area, possibly due to an addition of beds at the base and corresponds to the lowermost 100 feet of grey shale, interbedded with minor evaporitic carbonates of Member 3 in the Crickmay area.

The remaining, underlying Elk Point Group that consists of the Red Bed Unit - 500 feet thick - in the eastern part of the thesis area increases in thickness to the east and is over 800 feet thick in the Elk Point area.

The pink and red, sandy and shaly dolomite that is at the top of the Red Bed Unit extends easterly, beyond the thesis area. It thins from 150 feet to less than 50 feet in a south-north direction to the east of the thesis area. The dolomite probably correlates with (at least the major part of), Crickmay's Member 4, which at Anglo Canadian Elk Point No. 11 consists of 15 feet of red shale, underlain by 35 feet of sandy and silty red dolomite.

The interval immediately below the dolomite that contains some salt in the eastern part of the thesis area (cf. Fig. 3) corresponds to Crickmay's Member 5, i.e. the "Second salt" of McGehee; the underlying silty and evaporitic section (cf. Fig. 3) corresponds to Crickmay's Member 6; the coarse, sandy interval below (at 5920' on Fig. 3) corresponds to Crickmay's shaly Member 7; and the lowermost part of the Red Bed Unit that contains some salt in the eastern thesis area (cf. Fig. 3) corresponds to Crickmay's Member 8 or to the "Third salt" of McGehee.

In northwestern Alberta and adjacent to the area discussed in the thesis, the Watt Mountain Formation was described by Law (1955) as between 10 and 155 feet thick and consisting of varied detrital material. Law commented: "The lithologic character of the unit is controlled to a large extent by the distance from the Peace River land mass."

The interval equivalent to the Clastic and Evaporitic Unit of the thesis is represented in northwestern Alberta by the Muskeg and the Keg River Formations of Law (see p. 5). These grade from zero over the Peace River land mass to over 1100 feet in the northwestern part of northwestern Alberta.

The Upper "zone" (of the thesis) corresponds to the major part of the Muskeg Formation which in northwestern Alberta contains evaporitic and carbonate facies and is at a maximum 800 feet thick.

The Shale "zone" (of the thesis) is the lowermost part of the Muskeg Formation and thins down across northwestern Alberta from over 40 feet to less than ten feet, but can be traced as a thin shaly, and locally silty or sandy, layer as far north as the Cameron Hills area of Northwest Territories (Suska, 1961). Where the zone is thicker and evaporitic in northwestern Alberta, abundant chara were observed (cf. p. 43).

The Dolomite and Lower "zones" (of the thesis) are represented in northwestern Alberta by the dolomitic and limy Keg River Formation (see pp. 41 & 42) which attains there a maximum thickness of 350 feet.

The Red Bed Unit (of the thesis) appears to coincide with Law's redbeds, although locally Law included with the redbeds the maroon and green shales and sandstones which are probably of Cambrian age. His redbeds as such are less than 300 feet thick in northwestern Alberta. Farther to the north along the boundary of Northwest Territories an equivalent of the Red Bed Unit is absent (Suska, 1961).

In northwestern Alberta an avaporitic Chinchaga Formation that is up to 250 feet thick, is present below the Keg River Formation (i.e., below the apparent equivalent of the Red Bed Unit. At the base of the Chinchaga Formation an interval that may be analogous to the Assineau Sandstone was mentioned by Law: "In some wells light grey, fine to coarse-grained quartz sand and dolomitic sandstone occurs near the base of Chinchaga Formation". An interval equivalent to the Chinchaga Formation appears to be absent in the area of the thesis and farther east.

In conclusion, it becomes apparent that the northeastern area of this thesis is situated along the central belt of the thickest Elk Point development in Alberta.

The sequence of the Clastic and Evaporitic Unit in northeastern part of the thesis area resembles that of central Alberta, although it is possible that in central Alberta an additional small thickness of clastic beds is developed at the base of the Unit.

In northwestern Alberta, the evaporitic beds equivalent to the Upper "zone" of the Clastic and Evaporitic Unit of this thesis are thicker than elsewhere in Alberta and so is the carbonate section of the underlying part of the Unit (i.e. the equivalent of the Dolomite and Lower "zones"). Furthermore, an additional lowermost

evaporitic section, that of the Chinchaga Formation, is present in northwestern Alberta above the top of the redbeds (the Red Bed Unit). This means that the locus of maximum deposition of the Clastic and Evaporitic Unit was in northwestern Alberta and, furthermore, that an evaporitic basin was developed there that was absent in north-central and central Alberta, prior to, or at the beginning of deposition of the Clastic and Evaporitic Unit.

A comparison of Maps 10 and 11 of the thesis and of Figures 11 and 12 of Law's Paper points to an overlap of the consecutive zones of the Clastic and Evaporitic Unit on top of the Red Bed Unit. The overlap indicates a probable regressive phase at the end of the Red Bed Unit. The uppermost dolomite of the unit possibly represents that phase.

The lower sequence of the Red Bed Unit of this thesis is highly evaporitic and contains two major salt beds in eastern north-central Alberta and in central Alberta. In the northwest the sequence is considerably thinner and primarily shaly. This means that the evaporitic basins of the Elk Point Group probably did not develop in northwestern Alberta until later Elk Point time.

PRE-DEVONIAN UNCONFORMITY

In north-central Alberta a considerable unconformity separates Cambrian strata in the south and Precambrian strata in the north from the overlying Middle and Upper Devonian sediments. Some evidence of the time and of the amount of the pre-Devonian uplift is available.

Time and Amount of Pre-Devonian Uplift

A comparison of the truncation limits of the Cambrian units and of their isopachous contours with the extrapolated isopachous contours of the uneroded Cambrian units indicates that the northern map area was uplifted in post-Cambrian and pre-Devonian time (see Maps 1-8). The mean north-south gradient of the uplift was 5 feet to a mile. A gentle southward swing of the Cambrian isopachous and subcrop contours in the southwest might indicate that that area also was gently uplifted in the post-Cambrian time (see also p. 54).

Evidence of pre-Devonian tectonic movements (possibly associated with the uplift) is apparent from the comparison of the character of the basal Paleozoic beds in the north and the south: basal Cambrian units in the south display a lateral uniformity indicative of an almost level pre-Cambrian surface (see Maps 3-5 and p. 47); basal Devonian units in the north display sharp anomalies indicative of a sharp relief on the Precambrian surface which follows distinct linear trends; farther to the south the pre-Devonian relief indicated on the Cambrian surface is more subdued (see Maps 10, 12 and 13, and following pages). These data suggest that the origin of the sharp relief in the north is post-Cambrian and pre-Devonian and furthermore it suggests that the pre-Devonian relief is not entirely an erosional feature but that it reflects a pre-Devonian and post-Cambrian tectonic pattern.

Surface of Pre-Devonian Unconformity

The elements of the pre-Devonian surface of north-central Alberta may be derived from the study of the paleogeology (Map 8) and indirectly from the study of the isopachous and facies patterns of the overlying Devonian strata (Maps 9, 10, 12 and 13).

The isopachous maps of the Devonian Elk Point Group (see Maps 9 and 10) illustrate a westward onlap of beds and indicate that during Middle Devonian time the area was progressively submerged and that the west remained as a land mass until Upper Devonian time. The pre-Devonian paleogeological map (Map 8) illustrates a major difference between the southern and the northern map areas. In the south the pre-Devonian surface is Cambrian; in the north it is Precambrian. Many other features of the pre-Devonian unconformity of these two areas differ.

On a regional scale, restoring the top of the Elk Point Clastic and Evaporitic Unit to a level plain, the southeastward slope of the pre-Devonian surface is considerably steeper in the north (close to 20 feet per mile) than in the south (5 feet per mile) (see Map 10), but both gradients are comparable to the gradient of a continental shelf.

On the local scale, the relief indicated is significantly rougher on the Precambrian in the north than on the Cambrian in the south (cf. isopachous and facies maps 10, 12 and 13).

Local Features of pre-Devonian Surface in Northern Map Area

In the north, sharp local anomalies are common in the facies and isopachous patterns of the Middle Devonian beds. An example is the Red Earth Creek area (see Maps 10, 12 and 13) and the Cadotte Lake area extending north and south from

Township 83, Range 17, West 5th Meridian (see Map 13). Locally in the north, the lithology of basal Devonian beds illustrates variations that are usually associated with faults in the underlying surface, for example in the Three Creeks-Deadwood area extending between Township 89, Range 22 and Township 85, Range 18, West 5th meridian (see Map 13 and p. 47).

Local Features of pre-Devonian Surface in Southern Map Area

In the south the Middle Devonian facies and isopachous patterns illustrate broad gradations which indicate that the underlying surface has a more gentle relief than in the north. The structure of the Cambrian beds which are at the pre-Devonian surface is homoclinal with regional dips of some 10 feet per mile, mainly to the south (see p. 51); upon denudation, such structure could result in extensive cuesta scarps (the carbonate of Unit "e" underlain by a thick "d" shale is a possible example). Post-Cambrian faulting and/or folding, on the other hand, (cf. p. 51) would cause transverse folds on the regional homoclinal structure. Subsequent weathering and erosion would result in an undulating pattern of the subcropping Cambrian belts. Such a pattern is evident from Map 8.

It is difficult, however, to distinguish structural from erosional elements of this pattern. The erosional character of the Cambrian surface changes from north to south, that is from one unit to another, and it also changes laterally within the units as a result of facies variations. Some examples follow (see Map 8):

in the east a more pronounced erosion of the Cambrian strata might be explained by their weaker character in that area,

in the Virginia Hills area (tps. 65 and 66, rges. 12 and 13 W. 5th mer.) the irregularities of the erosional surface correspond to an abrupt facies change within Unit "f", i.e., it is a well-sorted medium-grained sandstone

of excellent porosity in the west and east, and a tight, limy and highly micaceous siltstone, grading to a fine-grained sandstone in the central area;

the anomaly developed in the Faust area (in the vicinity of tp. 71, rge. 10, W. 5th mer.) may be a result of a facies change within the upper Unit "c" (see Map 8);

similarly a pronounced erosional trend east of the Virginia Hills area (in the vicinity of tp. 65, rge. 13, W. 5th mer.) may be explained by an abrupt change of facies from a coarser and porous and probably more resistant sandstone to a siltstone within Unit "g";

another similar trend, extending to the north and south from the Prairie Creek area (tp. 70, rge. 17, W. 5th mer.) coincides with subcrops of weaker facies within the upper Unit "b" and within Units "c" and "e".

The trend of the Little Smoky River extending between tp. 75, rge. 22 and tp. 70, rge. 21, W. 5th mer., which experienced relatively less erosion, might be related to the resistant subcrops of the reefal Unit "c" to the south (see Map 8);

a southward swing of the subcrop outlines and isopachous contours in the west might be a result of a weakening character of Units "b", "c" and "d" in that area.

On the other hand, these irregularities might be better explained in terms of structural anomalies. For example, a more pronounced erosion of the Cambrian beds in the western map area may be in part, at least, a result of a greater uplift and/or a more prolonged erosion there; whereas some of the local anomalies described might reflect structural anomalies. This becomes apparent on comparing some trends of the pre-Devonian topography of the northern map area with those of the southern

map area (cf. Maps 10, 13 and 8): in the north some of the trends appear to follow tectonic patterns of the Precambrian surface (see pp. 52-53) and furthermore, these trends appear to continue into broader trends along the Cambrian surface in the south; thus they might reflect continuous structural trends of the map area. For example, one might find that the Little Smoky River anomaly is related to the Normandville fault (not illustrated on the maps but striking southeastwardly in tp. 79, rge. 22, W. 5th mer.), and that the Sturgeon Lake trend extends into the structural pattern of the western Belloy area (beyond the map boundaries) (see also p. 65).

MIDDLE DEVONIAN DEPOSITIONAL TRENDS

A controlling factor of the Middle Devonian deposition in north-central Alberta was the Peace River land mass or arch in the central northern area which extended into a southern ridge in the west. In the north this land rose abruptly from the sea. The southern map area formed a shallow, broad embayment and shelf, sheltered from the north by the Precambrian peninsula and flanked in the west by a more gently rising Cambrian terrain (see Maps 9, 10 and 13 and p. 52).

The striking aspects of the Middle Devonian deposits of the map area are:

a westward onlap of beds;

a change of facies from east to west; and

a different character of the onlap and of the facies change in the northern and in the southern map area.

Onlap and Western Facies of Elk Point Group

In the south the onlap of the Red Bed Unit of the Elk Point Group is associated with a broad westward transition of facies from evaporitic in the east to poorly-sorted clastic facies in the west. In the north, on the contrary, an

abrupt westward pinch-out of evaporitic beds of the Unit takes place.

Similarly, the Clastic and Evaporitic Unit in the south grades from mainly evaporitic in the east to shaly and silty and finally sandy in the west; and the lowermost red and unfossiliferous beds appear to be of continental origin. In the north the continental beds are uncommon and the evaporitic facies pinch out abruptly westward. Furthermore, in the south the thinning of each zone of the Unit to the west is gradual. In the north it is abrupt (see Maps 9, 10, and 12).

For example: in the south, Home Imperial Fina Grizzly Mountain No. 6-20 (tp. 70, rge. 7, W. 5th mer.) is 35 miles east and 80 miles east of the truncation line of the shale zone, and of the entire Unit, respectively. The Upper "zone" (195 feet thick) there is predominantly shaly and in the lower part of the Shale "zone" (100 feet thick) sandstone and siltstone are present. In the north, British American Bat Lake No. 6-31-84-7, W. 5th mer. is 10 miles east, and 20 miles east of the truncation line of the shale zone, and of the entire Unit, respectively. The Upper "zone" there (310 feet thick) is almost entirely evaporitic, and the Shale "zone" (approx. 100 feet thick) does not appear to be sandy.

The area of two Elk Point sandstones, the Assineau and the Gilwood, broadly coincides with the southern area of clastic facies of the remaining Elk Point Group (see Maps 11 and 13).

The feldspathic Assineau Sandstone wedges between evaporitic and shaly Red Bed and Clastic and Evaporitic Units. Its lithology indicates that the condition of deposition of the sandstone radically differed from that of the two units. The lower boundary of the Assineau is distinct but "floating sand grains" consistently present at the top of the underlying Red Bed Unit may mean that the change in conditions had already begun.

The lithology of the Assineau points to a period of active erosion at the source. The abundant feldspar indicates that the major source was in the granitic terrain in the north, because in the south Cambrian sediments underly the unconformity. On the other hand, the maroon coating on grains suggests erosion of the typically maroon basal Cambrian beds.

Poor sorting, and angularity of the grains and a high content of feldspar indicates that the sandstone was the result of relatively rapid deposition. The mode of deposition of the Assineau Sandstone is debatable: It could be a deltaic accumulation; or, an arkose wedge associated with an uplifted granitic terrain or associated with block faulting; or, more likely, a marine deposit of a reworked feldspathic residuum swept southward beyond the area of its origin by the marine currents of a transgressive sea.

A typical deltaic succession was not observed in the well cuttings but locally the sand is poorly sorted and lateral and vertical gradations into a finer sand and red and green shale occur, and coal might be present as mentioned on p. 38, cf. Krumbein and Sloss, 1958, p. 205. [The northern extension of a possible delta might have been the narrow Precambrian valley or trough which separated the main Peace River land mass in the west from the Cadotte high in the east, and which is apparent from maps of the younger Devonian intervals (see Map 13). It lies on strike with the thickest development of the Assineau, and perhaps it is this valley that flushed the coarse detritus into the Assineau lense?]

On the other hand, the Assineau Sand is abundantly glauconitic and anhydritic, which suggests a marine or a marine-reworked sediment (although both the anhydrite and the glauconite could have been precipitated in this highly porous and permeable sand after its deposition).

Krumbein and Sloss (1958, p. 131) believed that a strongly uplifted granitic terrain is generally a source of wedge arkoses, but although the Precambrian land in the northwestern map area had locally a fair relief, it appears doubtful (as indicated on pp. 52-53) if it could be classified as "strongly uplifted". Pettijohn (pp. 322-331, 1957) and Krynine (1941) elucidate that a wedge of sandstone of low maturity incomplete cementation, fair sorting and limited aerial extent (all of which complies with the character of the Assineau) may be associated with block faulting (and thus would be a good time marker of such an event). The thickness of the Assineau (not much over 200 feet), indicates that if such tectonic movements were responsible for its formation, they were only of minor intensity (e.g., the possible Cadotte-Peace River trough on Map 13). On the other hand, evaporitic facies not far to the east indicate that the Elk Point was generally a period of extreme tectonic stability in the map area.

An alternative interpretation is that the Assineau was deposited by off-shore currents that carried the eroded granitic material from the north on to the shallower Cambrian platform in the south. Such an interpretation would account for the character of this deposit (see p. 38) and it would explain why the distribution of the Assineau Sandstone laterally resembles the distribution of the clastic material of other Elk Point beds -- similar agents (but of unequal intensity?) may have distributed the detritus throughout the entire period.

The time of the deposition of the Assineau Sandstone is questionable. It is post-Red Bed Unit, and it is either entirely pre-Clastic and Evaporitic Unit, or it is a transgressive deposit equivalent to progressively younger zones of the Unit westward. In the first case it would be a product of a brief increase in the erosional and depositional activity; in the second case, it would be a product of a sea gradually encroaching upon the arch, that is a result of a continuous or, more likely, repeated subsidence.

The distribution of the younger Elk Point Sand, the Gilwood of the Watt Mountain Formation, parallels laterally the distribution of the detrital material on the underlying Elk Point beds, including that of the Assineau. In the north the true Gilwood of Watt Mountain age is absent except as local tongues of sand or of sandy grains imbedded in shale, that extend from the arch. In the south a continuous sheet of sand extends far into the true Watt Mountain Formation (cf. Maps 10 and 13). Thus it appears again that similar distributary agents were active during the Gilwood as during the previous Elk Point intervals.

The source, in part at least, of the feldspathic Gilwood must have been the same which supplied the Assineau, that is the granitic terrain in the north (or possibly the Assineau itself overlain by the Gilwood in the west). Abundant glauconite indicates a shallow marine origin. Therefore the Gilwood probably represents a "wash" material redistributed by marine currents and deposited in the shallower southern areas of the sea. This suggests a similar environment to the one proposed for the Assineau Sandstone, but the Gilwood sand is thinner, has a wider lateral extent, and a finer texture, which suggests more stable conditions that allowed a longer reworking of the detritus before deposition.



Eastern Facies of the Elk Point Group

The eastern evaporitic facies of the Middle Devonian Elk Point Group portrays the environment of a restricted intracratonic basin.

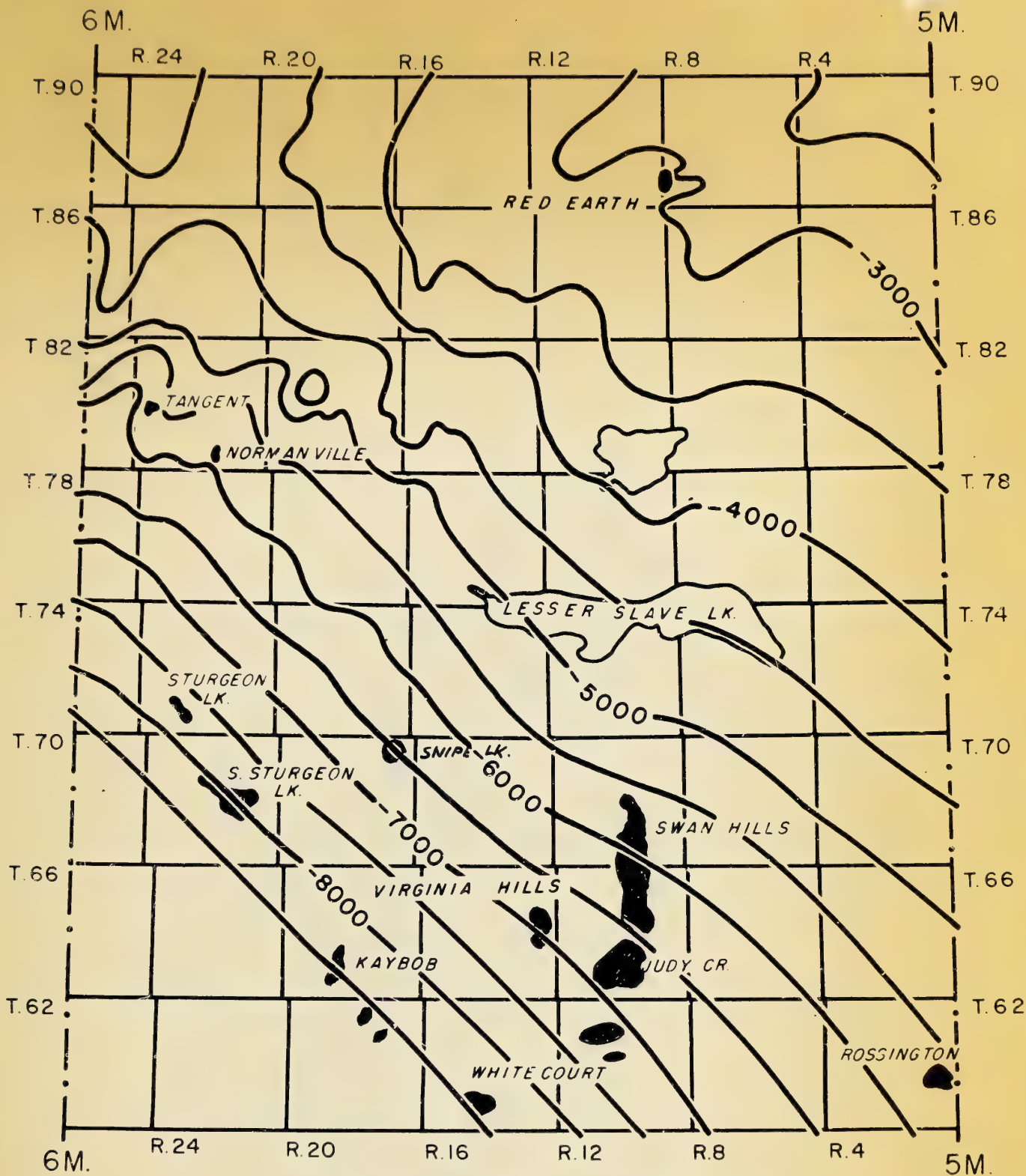
Repeated evaporitic phases may be distinguished within the Group in the eastern map area. A lower phase is contained in the upper part of the Red Bed Unit; and the upper phase in the Clastic and Evaporitic Unit; a third, lowermost phase is better apparent farther east, beyond the map boundaries. The deposition of the two phases of the map area appears to have followed somewhat analogous steps:

The easternmost facies of the lower evaporitic phase apparent in the map area is fully developed not far beyond the eastern map boundaries, e.g., at Imperial Grosmont No. 1, l.s. 13, sec. 17, tp. 67, rge. 23, W. 4th. It consists of a sandy shale overlain by an evaporitic interval which comprises mainly salt and anhydrite; overlain in turn by a pink and red, sandy and/or shaly and silty dolomite.

The easternmost facies of the upper evaporitic phase present in the eastern map area (the Clastic and Evaporitic Unit) comprises a dominantly shaly interval with a persistent reefal dolomite zone in the center (i.e., the Lower "zone", the Dolomite "zone" and the Shale "zone" of this paper); and an overlying evaporitic interval of which the uppermost dolomitic bed could be regarded as analogous to the pink dolomite of the preceding phase.

It may be noted that the upper evaporitic phase is overlain by a shaly interval of the Watt Mountain Formation in the same way that lower evaporitic phase is overlain by the basal shaly interval of the upper phase. Both these shaly intervals grade laterally westward into feldspathic sandstones, the Gilwood and the Assineau, respectively, indicating that each of the evaporitic phases was succeeded by an "outpour" of feldspathic sands from the northern shore regions.

Other shaly intervals lower in the Elk Point sequence are present farther east, beyond the map area (e.g. Crickmay's (1954) Members 9 and 7), but little is presently known on their westernmost facies. These intervals may indicate genetically similar horizons to those of the Gilwood and the Assineau, and perhaps together they present a record of at least four major pulsations during Elk Point time, each younger one marking a wider transgression of the sea.



STRUCTURAL CONTOURS
ON

TOP OF PRE-CAMBRIAN

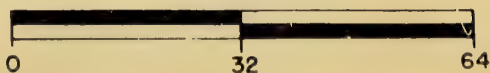


OIL FIELDS

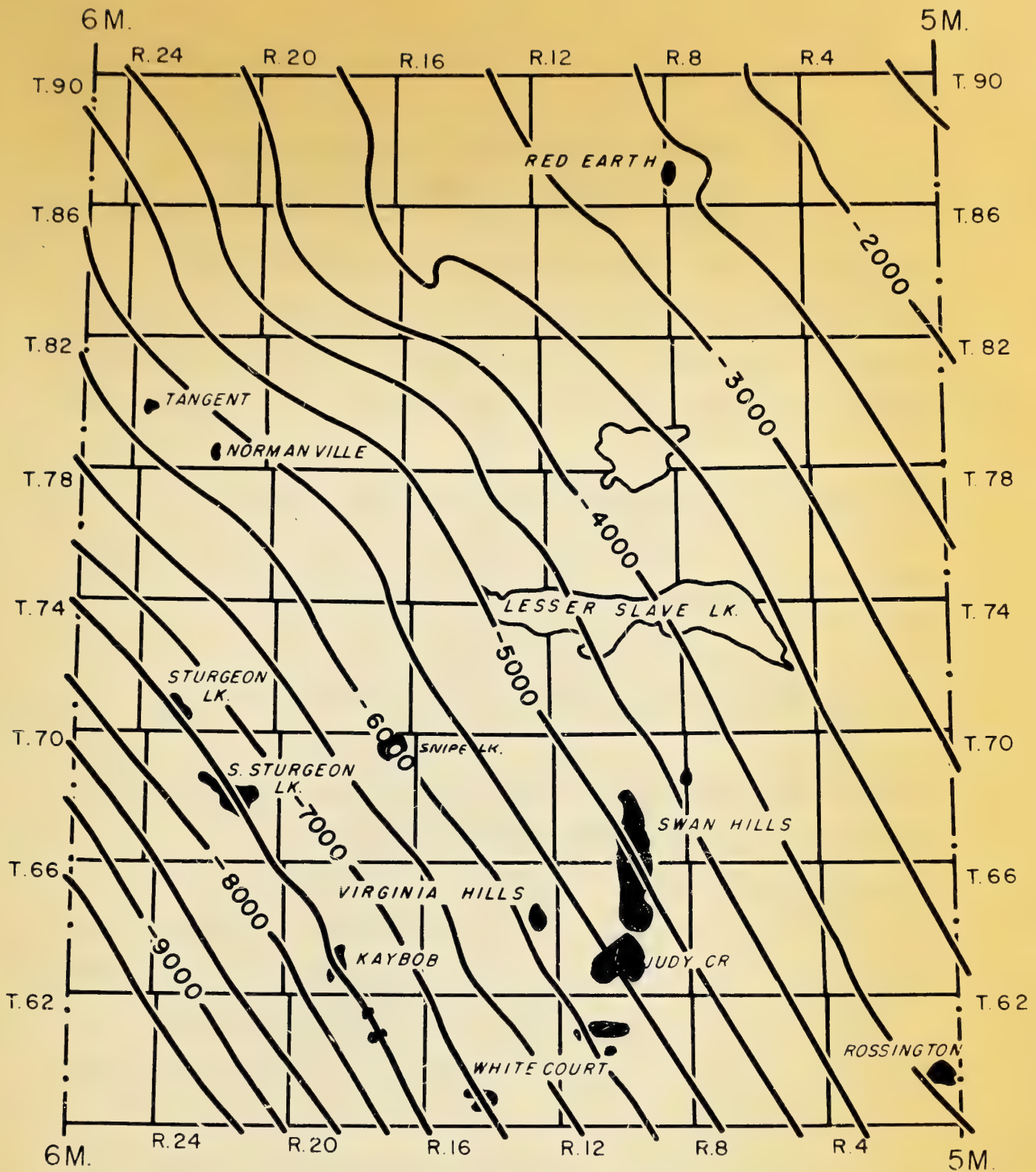


GAS FIELDS

MILES



MAP 14



STRUCTURAL CONTOURS
ON

TOP OF ELK POINT



OIL FIELDS



GAS FIELDS

MILES



MAP 15

GENERAL COMMENTS ON REGIONAL FACTORS
OF OIL AND GAS PROSPECTS OF THE MAP AREA

A detailed discussion of the oil and gas prospects is not within the scope of this work. A summary of the reservoir characteristics of the prospective Cambrian and Middle Devonian beds is outlined below. It is followed by generalised comments on factors which may have influenced the hydrocarbon entrapment within these beds in the map area.

A number of intervals of good to excellent porosity and permeability were observed in the Devonian Elk Point Group of the map area:

The Assineau Sandstone, illustrated on Map 11
the Gilwood Sandstone, illustrated on Map 13
the dolomite beds of the Clastic and Evaporitic Unit (see
Map 10), and
the Shale "zone" of that Unit, where it contains sandy develop-
ments, close to its southwestern truncation line (see Map 10).

To date, only the Gilwood sand within the Elk Point Group has been found to be productive. It yields oil production in the Gilwood area (tp. 73, rge. 18, W. 5th mer.); and in the Iroquois area (tp. 75, rge. 19, W. 5th mer.), where the Gilwood overlies directly the Precambrian, and thus merges there with the Granite Wash; the Gilwood yielded good shows of oil and gas at Pan American Giroux Crown No. A-1 (tp. 65, rge. 25, W. 5th mer.); and it produces gas at H.B. Union East Virginia Hills No. 1 (tp. 65, rge. 6, W. 5th mer.). In addition to the local variations related to stratigraphic and structural (?) changes (see Map 13) the complete northeastward, i.e., up-dip, pinch out of the Gilwood sand is of major economic interest.

The Assineau Sandstone has yielded very large quantities of salt water, wherever tested. The writer observed dead oil stain in samples of the Assineau at a few wells of the map area. This sand (see Map 11) is believed by the writer to be a major oil and gas prospect: it has excellent reservoir character; it immediately overlies a number of erosionally truncated Cambrian beds of excellent porosity in the southwest; and it pinches out, regionally up-dip. It is not known whether or not northeastwardly it passes into local tongues of Granite Wash sands, and, if so, how far these might continue (e.g. along faults of the basement?). The structure of the pre-Devonian unconformity which underlies the Assineau in the major western map area is another factor to be considered when studying the oil and gas prospects of this sand.

Porous sandy facies are also developed within the Shale "zone", of the Clastic and Evaporitic Unit, mainly where this "zone" immediately overlies the Assineau and where both constitute one porous horizon; however, it is possible that the porous facies of the Shale "zone" persists northeastwardly beyond that area and into the region where the Dolomite "zone" underlies it. Such a situation would create excellent entrapment conditions because still farther to the northeast, i.e. up-dip, the Shale "zone" is entirely shaly.

Sucrose dolomite developments up to 20 feet thick with good to excellent porosity are common in the Dolomite "zone" of the Clastic and Evaporitic Unit. The zone has not been widely tested but locally yielded large quantities of salt water. Dead oil stain was observed within that zone at a few wells of the map area. Northeastwardly, beyond the map area the zone is tight and therefore good regional possibilities for the stratigraphic entrapment in the proximity of the eastern map boundaries are present.

In the north a similar situation exists with the stringers of the sucrose dolomites of the Lower "zone" of the Clastic and Evaporitic Unit.

Granite Wash sands, developed at the base of the Devonian section, locally contain thick sandstone lenses of excellent intergranular porosity. Generally, the distribution of these sands appears to be related to the anomalies of the basement. To date, they have yielded oil production in the Red Earth area, situated mainly in townships 87 and 88, range 8 west of the 5th meridian; at the Loon Lake well No. 10-3 (tp. 87, rge. 10, W. 5th mer.), in the Iroquois area (tp. 75, rge. 19, W. 5th mer.)(see previous page), and very recently at Atlantic Utikuma Lake No. 10-27 (tp. 81, rge. 9, W. 5th mer.). Large quantities of salt water and shows of hydrocarbons were recorded at many other wells tested.

Cambrian units of the map area contain wide intervals of excellent porosity and permeability. Such intervals are common in the basal Cambrian sands of the main part of Unit "a". The uppermost shale of "a", on the other hand, provides an excellent cap rock except in the northernmost area where it is not developed and where no impermeable barrier exists between "a" and the overlying porous "b"; and also, where "b" is absent between "a" and the Devonian sands, Assineau in the east and Gilwood in the west. The sands of Unit "a" have yielded large quantities of salt water wherever tested in the north where they directly underlie the pre-Devonian unconformity and also at many wells of the southern area where they underlie the younger Cambrian beds. They yielded small gas shows in the Gilwood area. Dead oil staining within these sands was observed by the writer at two wells of the southwestern map area.

It was indicated previously that good to excellent porosity developments are common in the sandy intervals of Unit "b". These are mainly developed in the lower half of the unit in the area indicated in yellow on Map 4 and usually throughout the unit in areas marked in pink. In other areas the porosity developments are poor to absent. Unit "b" has not been extensively tested except at a few wells of the southwestern (pink) area where, to date, it has yielded large quantities of salt water. At two southwestern wells where the porosity is not good, the writer observed dead oil

stain in the samples of "b" sandstone. Conditions favorable for stratigraphic entrapment are present in the southeast, where the unit shales out up-dip and where it is overlain by the shaly "c" and possibly also in the southwest (cf. Map 4).

Within the yellow, predominantly sandy area on Map 4, Unit "c" commonly contains zones, some 20 feet thick on the average, of excellent intercrystalline porosity. In the bluish-green area scattered thinner intervals of fair to good intercrystalline porosity were observed. In the western, violet area reefal dolomite intervals, up to 45 feet thick, of excellent vug and intercrystalline porosity are present. The "c" reefal dolomite has been tested at a few localities and yielded large quantities of salt water. At one well in the northwest, dead oil stain was observed in the samples from that dolomite. The sandstones of Unit "c" have only been tested at a few localities where they have yielded large quantities of salt water. Dead oil stain was observed in samples of that sandstone at a few wells. It is apparent from Map 5 that the regional trends of "c" facies are not favorable for stratigraphic entrapment. Local irregularities of these trends could improve the prospects considerably. The immediately overlying "d" shale constitutes an excellent impervious cap.

Unit "e" contains excellent vug and intercrystalline porosity throughout the area where its coarse facies are developed (see patterned area of Map 7). An up-dip pinch out of these facies is apparent in the west central map area. However, "e" is directly overlain (with a shaly and/or silty bed only locally developed in between) by the "f" sandstone which contains excellent porosity and permeability developments throughout the western area. Unit "f" has been tested at a number of wells and invariably has yielded large quantities of salt water.

Carbonates of Units "g" and "h" underlie only the southernmost map area. Their reservoir character at the pre-Devonian subcrops is illustrated on Map 8.

Thus, in summary, Cambrian units of the map area contain wide intervals of excellent porosity and permeability. However, their principal aspect is their progressive erosional truncation at the unconformity which might have resulted in a spill, or in the migration of hydrocarbons into the overlying sediments where these are porous and permeable. Map 8 illustrates subcrops of Cambrian beds and their fair to excellent porosity developments (light and heavy dots, respectively). In the east where the impervious Red Bed Unit overlies (see Map 9) the prospects at the unconformity are good. In the western area the Cambrian is overlain by the Elk Point beds of varying but generally excellent reservoir character, mainly the porous and permeable Gilwood Sandstone in the west and the porous and permeable Assineau Sandstone in the major central map area (see Maps 11 and 13). As was discussed previously, permeable connections among these Elk Point rocks are in turn also present.

The writer met commonly with an opinion that in the area discussed a source is absent for the Cambrian reservoirs and that therefore they are unproductive. However, dead oil stain was observed in these rocks and there is no proof that hydrocarbons could not have originated within them. Furthermore it appears quite possible that hydrocarbons could have migrated into these rocks (if such migrations truly take place) from the immediately overlying Devonian strata, provided that other physical conditions were favorable; for example, beyond the western map boundaries the Cambrian unconformity is immediately overlain by Upper Devonian shales which are believed to be the source for most of the Devonian reservoirs. A changing load of sediments would be one factor influencing a migration and a question might arise whether the Cambrian load was sufficient for the migration and consequently the escape of oil at the surface of the unconformity in the pre-Devonian time. A changing tilt of sediments would be another factor. The pre-Devonian tilt of Cambrian beds was of the order of 10 feet to a mile to the south; at the close of the Devonian time

the additional depositional tilt was of the order of 10 feet per mile to the east, and at the close of the Paleozoic the additional tilt was 15 feet to a mile to the northwest; a final major Mesozoic and later tilt was some 25 feet to a mile to the south-southwest in the main map area. If a migration of hydrocarbons took place it could have, therefore, followed a number of stages. A problem which such a situation creates is, for example, whether the tilt of Devonian beds was at one time sufficient for a possible migration of hydrocarbons from the Assineau into the connecting Gilwood and younger sands westward.

The existing regional structure in north-central Alberta is homoclinal to the southwest with average dips of 35 feet to a mile on top of Precambrian and Middle Devonian beds (Figs. 2 and 3), and 30 feet to a mile on top of Cambrian strata.

Little is known of the local structural anomalies. Observations made by the writer and by others (personal communication) immediately to the northwest of the area discussed, that is, where Cambrian strata are absent, appear to show that some pre-Devonian anomalies such as faults were the loci of later tectonic movements, e.g., the Normandville field area. An analogous situation may exist in the southern map area and is indicated by repeatedly similar trends of Cambrian, Devonian and later depositional anomalies (e.g. Sturgeon Lake area, see p.32).

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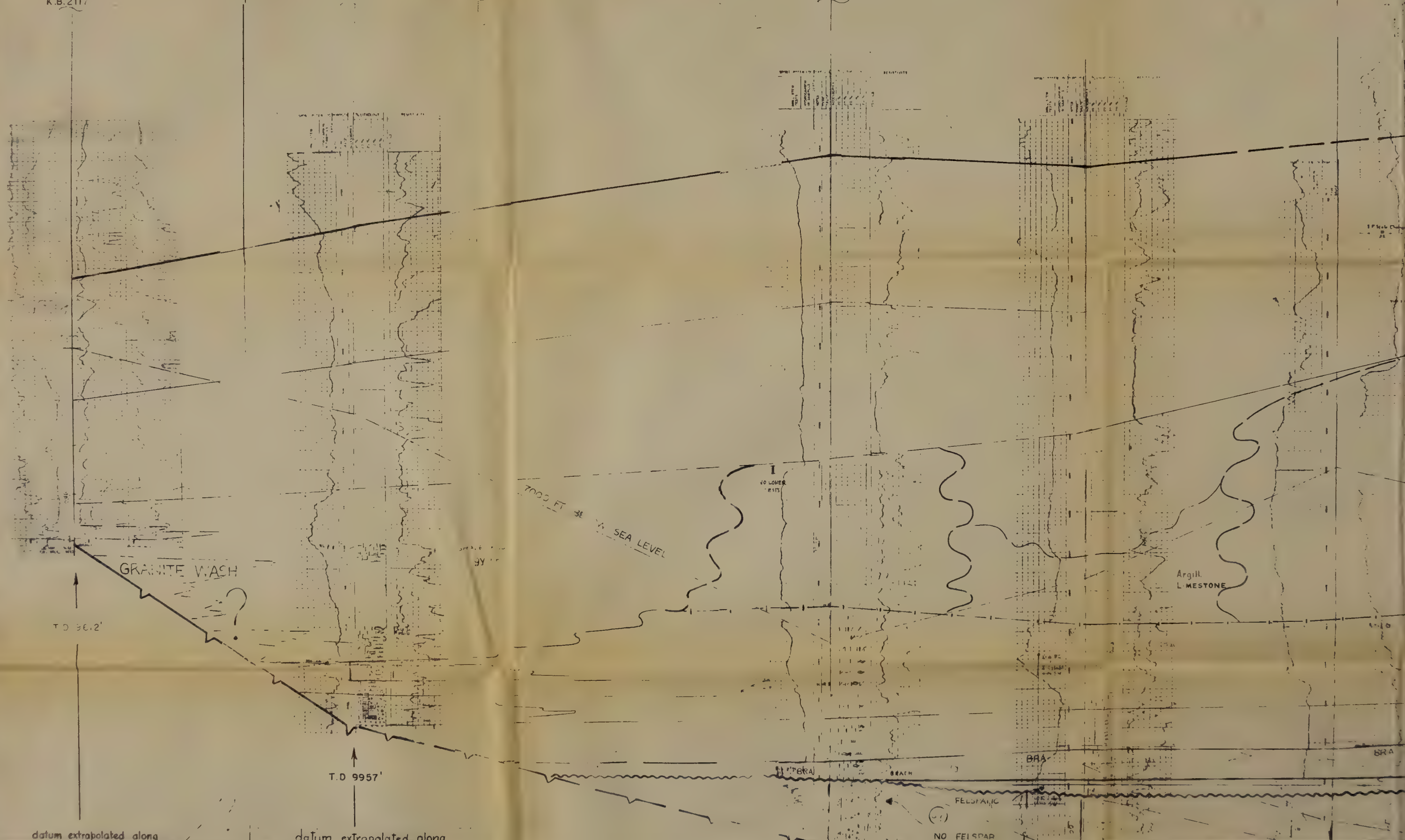
CAL. STANDARD
SMOKY RIVER 13-20
13-20-75-2W6
K.B.2117'

2
AMERADA
CROWN AY6-7
6-7-74-26W5
K.B.2154'

3
AMERADA
CROWN HF 34-5
2-5-72-23W5
K.B.2758'

4
MOBIL AMERADA
NO 1-11
1-11-70-23-W.5
K.B.2368'

5
HB. UNION LIBERAL
GULF 1.
3-5-68-22W5
K.B.2297'



datum extrapolated along

datum extrapolated along

5

6

7

8

9

10

LIBERAL

GULF

STANOLIND

PHILIPS

CAL. STANDARD GULF

FINA PAN. AM.

GULF 1

LITTLE SMOKY 1-27

GIROUX LAKE 1.

KAYBOB 1. (New N^o. 7-22)

KAYBOB 5-35

SILVER CREEK 7-12

5-5-68 22W5

1-27-67-22W5

6-20-65-20W5

7-22-64-19W5

5-35-62-18W5

7-12-61-16 W5

KB 2297'

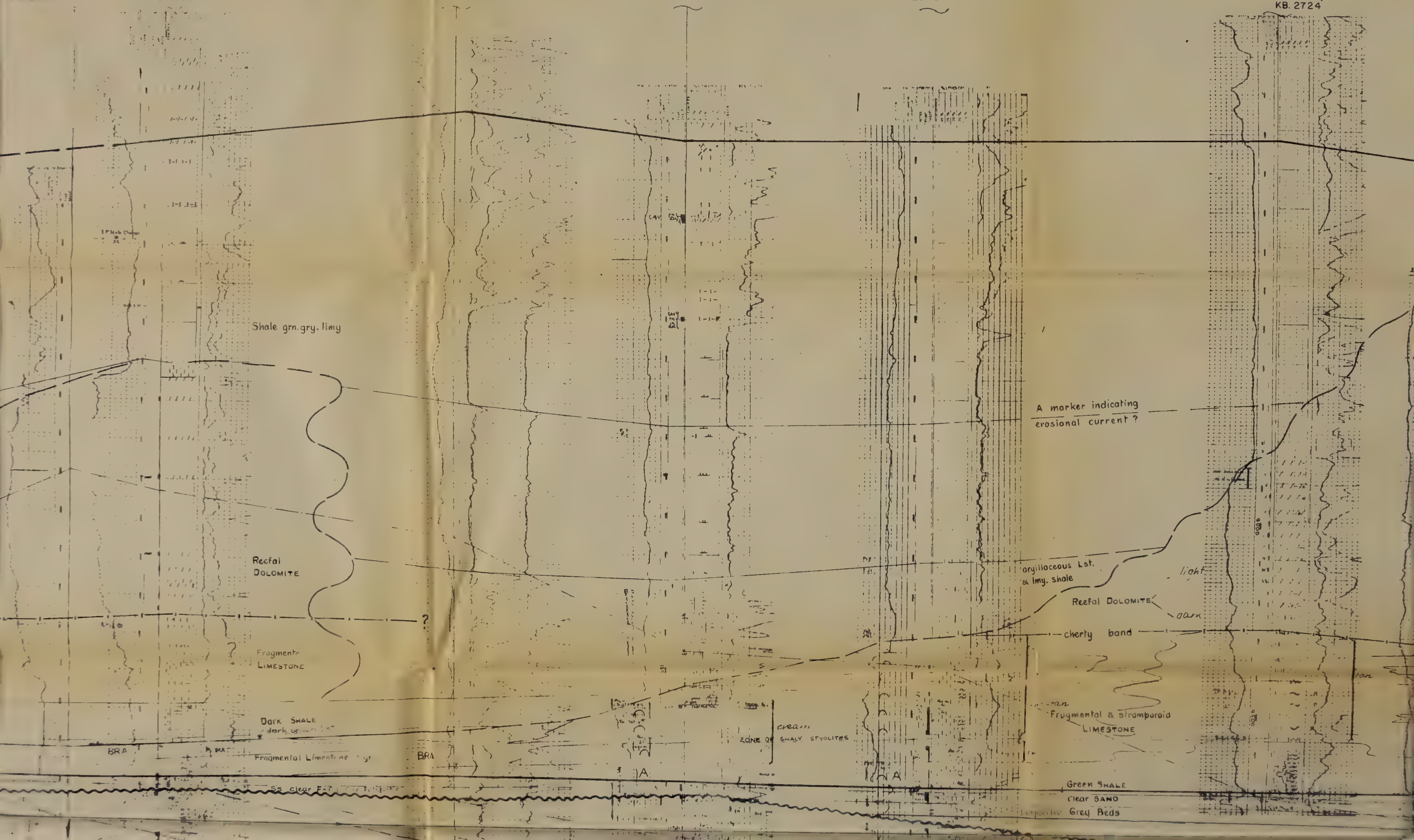
KB 2233'

KB 2426'

K.B. 2450'

K.B. 2878'

KB. 2724'



10

FINA PAN. AM.

SILVER CREEK 7-12

7-12-61-16 W5

K.B. 2724'

11

FINA STANOLIND H.B.

WINDFALL 12-36

12-36-59-15 W5

K.B. 2786'

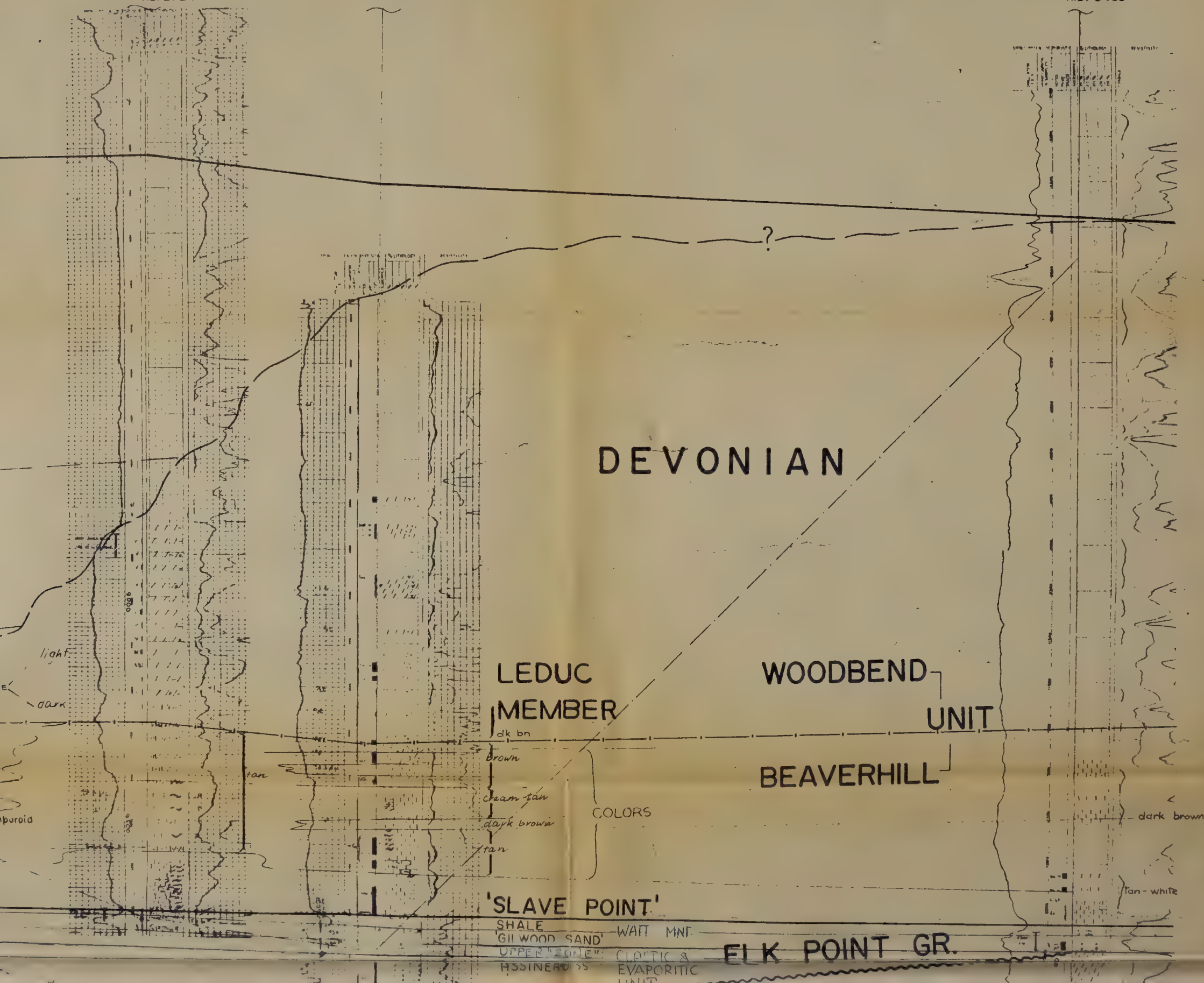
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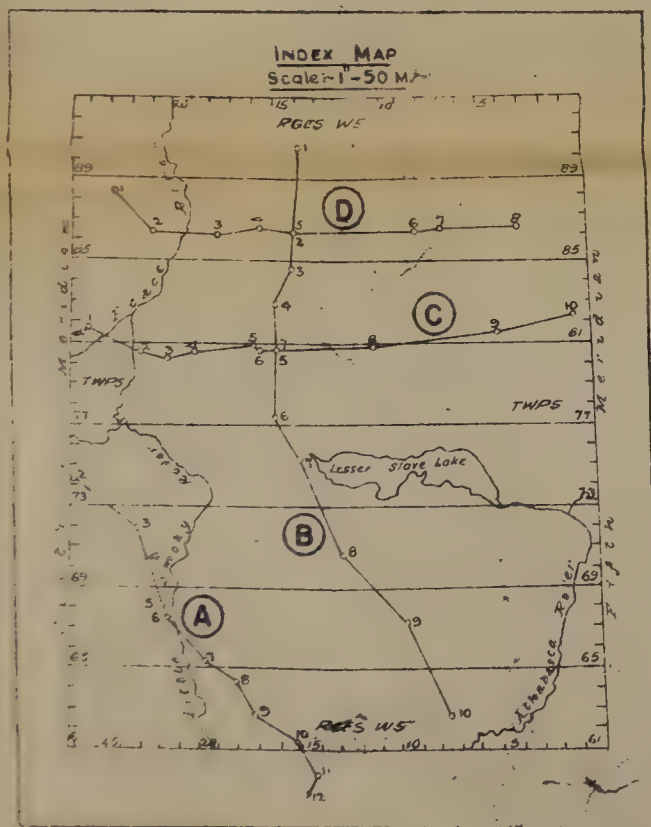
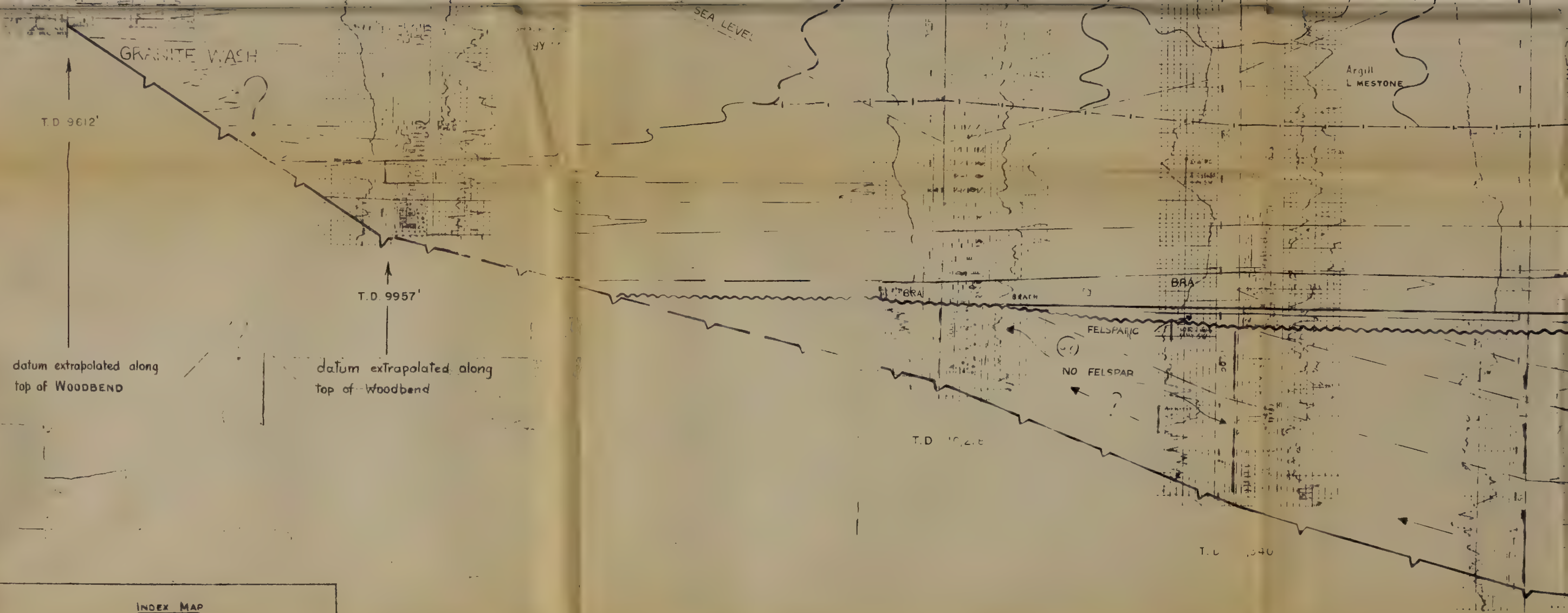
FINA STANOLIND H.B.

SUNDANCE 15-29

15-29-55-17 W5

K.B. 3465'





STRATIGRAPHIC CROSS SECTION A OF EARLY PALEOZOIC SEDIMENTS

HOR. SCALE APPR. 1 INCH = 4 MILES
VERT. SCALE 1 INCH = 200 FEET

DATUM: BASE OF 'SLAVE POINT'



A

- COLOR**
- 1 Limestone grey-tan, very fine x argillaceous grading to limy shale
 - 2 Limestone light grey-tan, Kpx fine x, uniform dense, may contain scattered fragmental fossils
 - 3 Limestone buff-brown, fine coarse x B & Cx & silt frag. (pelletoid) porosity poor-fair
 - 4 Limestone white, buff & very light grey, M-Cx, uneven B coarse frag. with frag. porosity poor-good
 - 5 DOLOMITE white, cream & light grey, F-Cx, locally frag. porosity fair-excellent
 - 6 DOLOMITE tan-grey, light brown, Cx, x, locally sub frag. porosity poor-good
 - 7 DOLOMITE white, cream & light grey, F-Cx, locally frag. porosity fair-excellent
 - 8 PETROLIFEROUS Limestone DOLOMITE dark brown, F-Cx, locally frag. porosity fair-excellent
- BRA** Brachiopods & associated fauna
A Amphipods & associated fauna
n Stomatopoda & associated fauna

T D 11,320'

LEDUC
MEMBER

WOODBEND
UNIT

BEAVERHILL

COLORS

'SLAVE POINT'

SHALE
GILWOOD SAND
UPPER "ZONE"
ASSINEAU SS
WATT - MNT.
CLASTIC &
EVAPORITIC
UNIT

ELK POINT GR.

CAMBRIAN

PRE-CAMBRIAN

T.D. 10,930'

T.D. 12,928'

M. M. SUSKA
CALGARY-EDMONTON

1
CAN. SEABOARD
NORTH CADOTTE 15-24
15-24-90-15 W.5
K.B.2431'

2
CAN. SEABOARD
CADOTTE 10-16
10-16-86-15-W5
K.B.1959'

3
CAL. STANDARD
CADOTTE RIVER 4-29
4-29-84-15 W5
K.B.2308'

4
CAL STANDARD
BEARHEAD 1
8-34-82-16 W5
K.B.2293'

5
UNION
NORTH HEART
5-23-80-1
K.B.239

WOODBEND
BEAVERHILL
UNIT

5

UNION EVANS
NORTH HEART RIVER 5-23
5-23-80-16 W5
K.B. 2392'

6

H.B. UNION
HEART RIVER I.
4-17-77-16- W.5
K.B. 2315'

7

IMPERIAL
GROUARD I.
12-16-75-15 W5
K.B. 1917'

8

STANOLIND
HOUSE MOUNTAIN I.
7-29-70-13- W5
K.B. 2557'

3,000 FEET BELOW SEA LEVEL

8

STANDLIND
HOUSE MOUNTAIN I.
7-29-70-13-W5
K.B. 2557'

9

HOME ET AL REGENT
EDITH LAKE II-19
11-9-67-10-W5
K.B. 3500'

PAN AMERICAN
MORSE RIVER A1.
4-13-66-10W5
K.B. 3661'

10

MOBIL OIL
GOOSE CREEK 10-20
10-20-62-8 W.5
K.B. 2548'

Limy Shale

Shaly Limestone
& Limy Shale

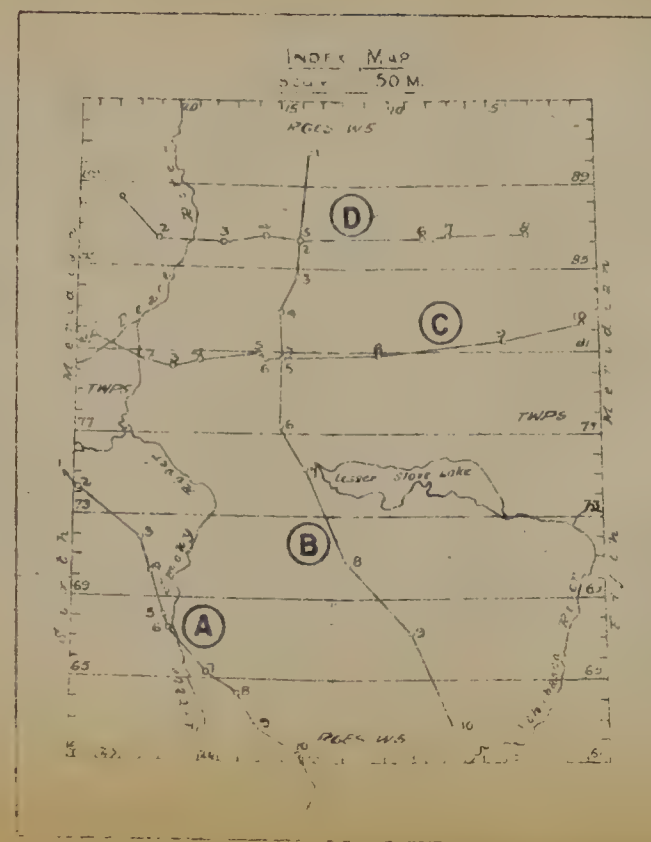
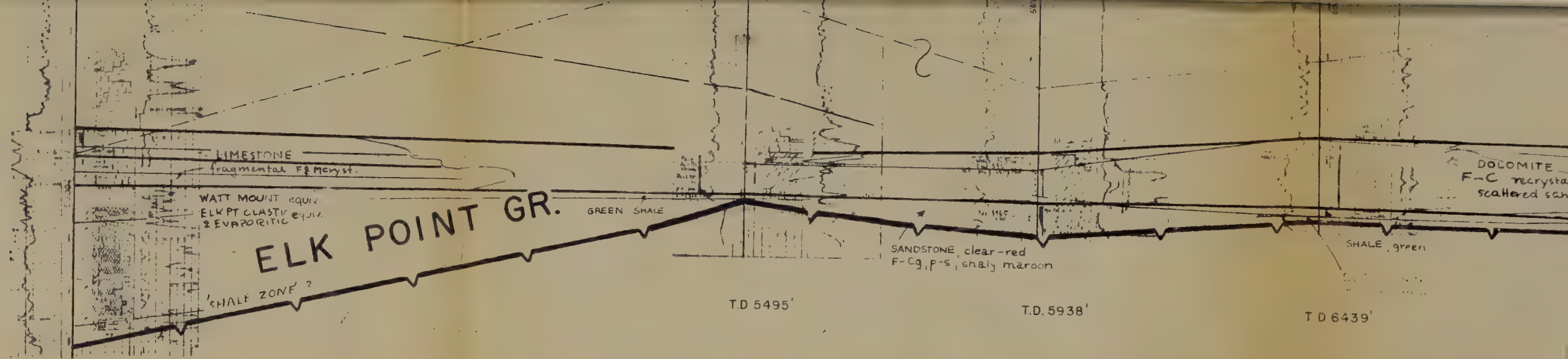
DEVONIAN

WOODBEND

BEAVERHILL

UNIT

BEAVERHILL EQUIV. ?

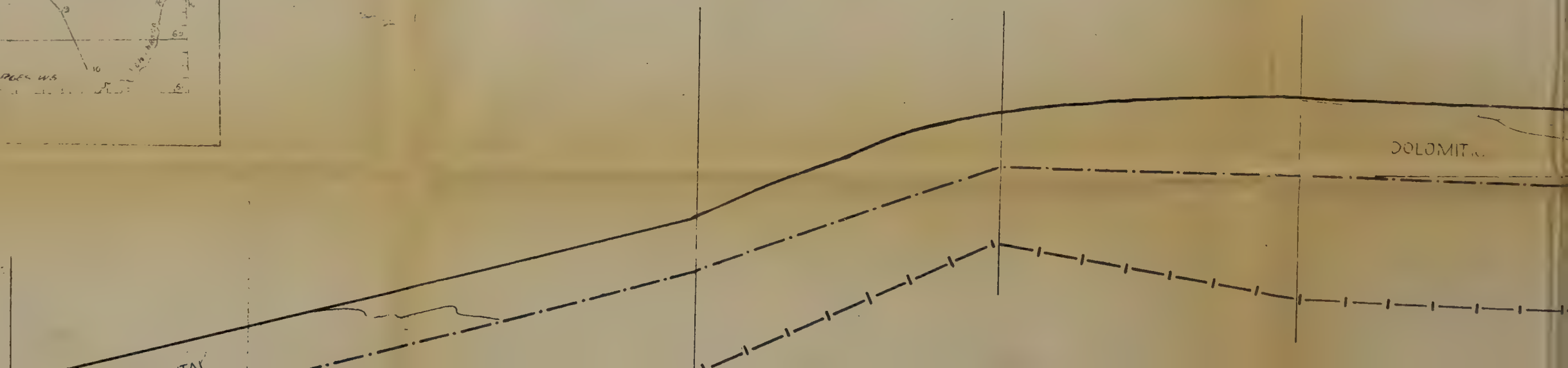


STRATIGRAPHIC CROSS SECTION (B) OF EARLY PALEOZOIC SEDIMENTS

HOR. SCALE APPR.: 1 INCH = 4 MILES

VERT. SCALE: 1 INCH = 200 FEET

DATUM: BASE OF 'SLAVE POINT'





B

- COLOR LEGEND - SLAVE POINT**
- 1 Limestone grey-tan, very fine x, argillaceous grading to LIMY SHALE
 - 2 Limestone light grey-tan, Kpx-fine x, uniform dense, may contain scattered fragments - dense
 - 3 Limestone buff-brown, fine-coarse x & sub x & sub frag. locally frag (pelletoid) porosity poor-fair
 - 4 Limestone white, buff & very light grey, M-Cx, uneven & coarse frags sub frags stromatopora common, porosity fair-excellent
 - 5 DOLOMITE tan-brown, Fx-Mx, tight
 - 6 DOLOMITE tan, grey, light brown, F-C, x-rx, locally sub frag porosity popr-good
 - 7 DOLOMITE white, cream & light grey, F-C, rx, porosity fair-excellent
 - 8 PETROLIFEROUS Limestone DOLOMITE dark brown, F-Cx, locally frag. amphipora common porosity tight-poor
- BRA Brachipods & associated fauna
A Amphipora
~ Stromatopora & associated fauna

Shaly Limestone
& limy shale

WOODBEND

BEAVERHILL

UNIT

BEAVERHILL EQUIV.?

LIMESTONE
Fcryst - fragm.

LIMESTONE
chiefly stromatoporeoidal
M-C fragmental & M-C recryst.

"SLAVE-POINT"

FORT VERMILION MEMBER?

GILWOOD SAND

ELK PT CLASTIC
& EVAPORITIC
UNIT

ELK POINT GR.

upper zone

Shale zone

Massive sand

Evaporitic

(DOLOMITE ZONE)
10' only

RED BED UNIT

SHALE (Mostly)
green - maroon

DOLOMITE grading SANDSTONE
creamy-grey
with green-maroon SHALE

SANDSTONE grading DOLOMITE
light colour
with grey-green-mar. SHALE & ANHYDRITE

CAMBRIAN

PRE-CAMBRIAN

T.D. 8177

T.D. 9572'

T.D. 9820'

(g)

(f)

(e)

(d)

(c)

(b)

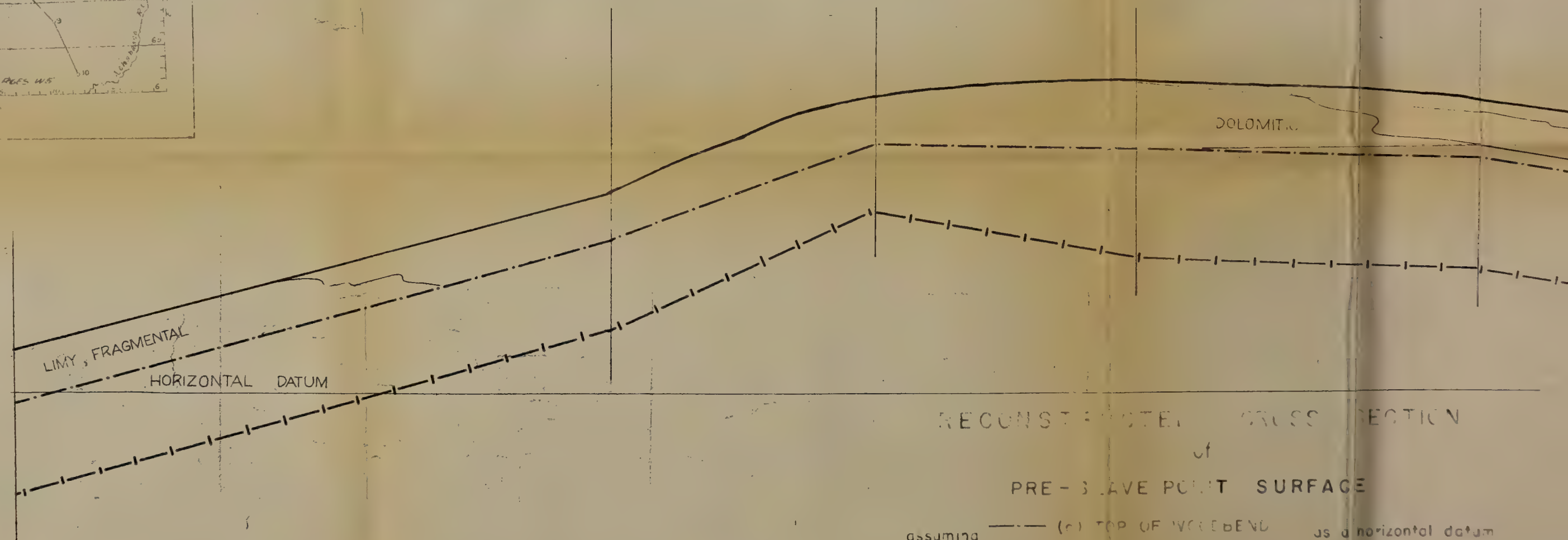
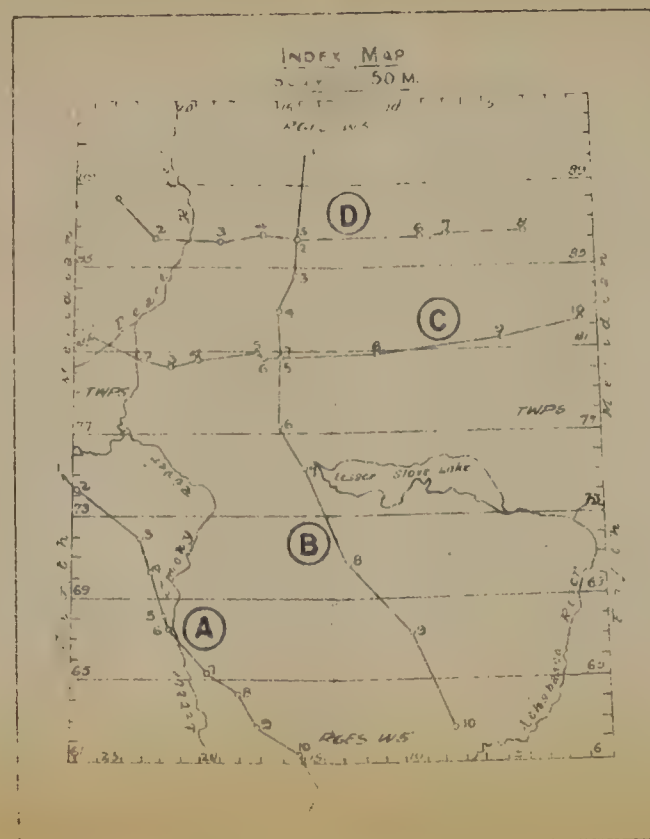
(a)

STRATIGRAPHIC CROSS SECTION (B) OF EARLY PALEOZOIC SEDIMENTS

HOR. SCALE APPR: 1 INCH = 4 MILES

VERT SCALE : 1 INCH = 200 FEET

DATUM: BASE OF 'SLAVE POINT'

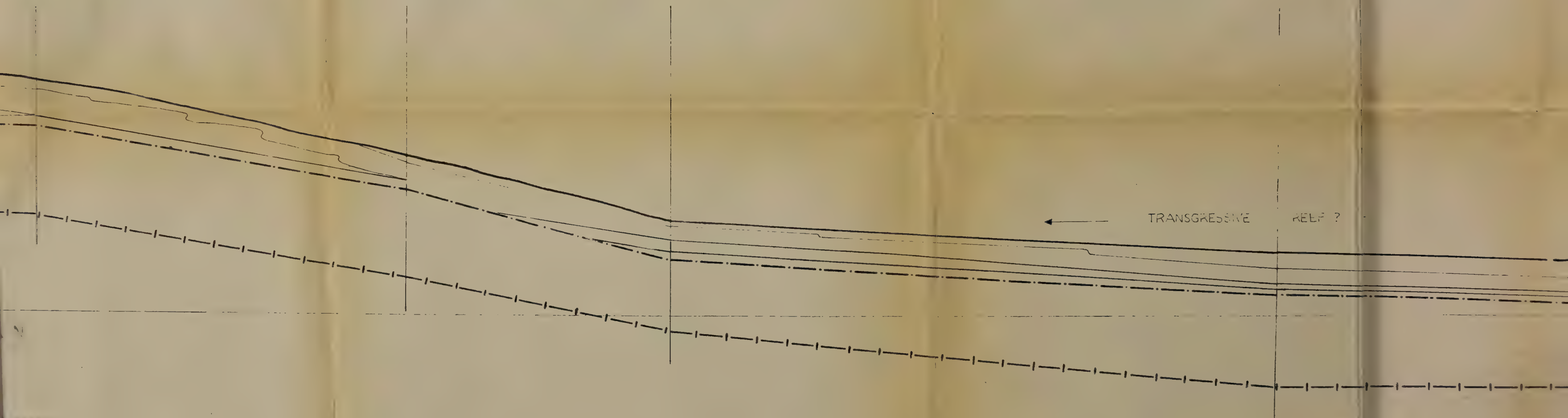


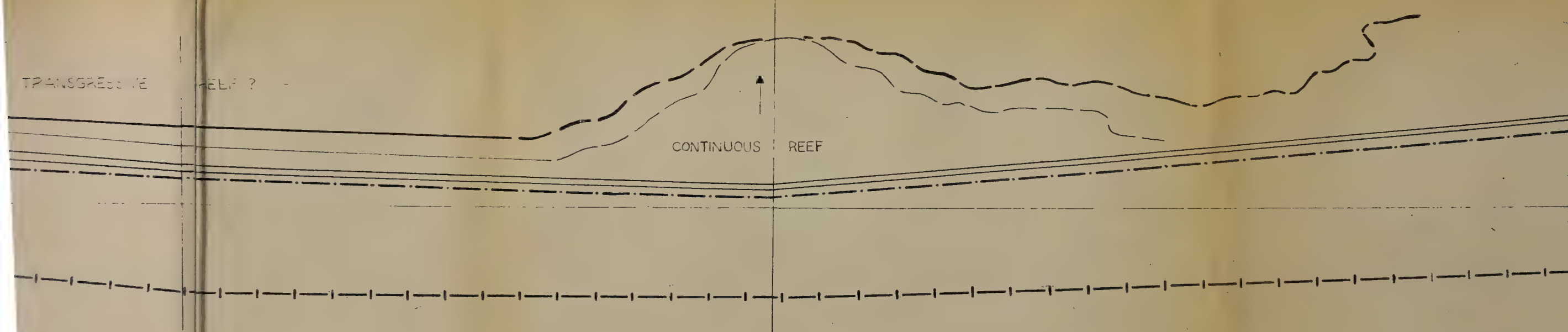
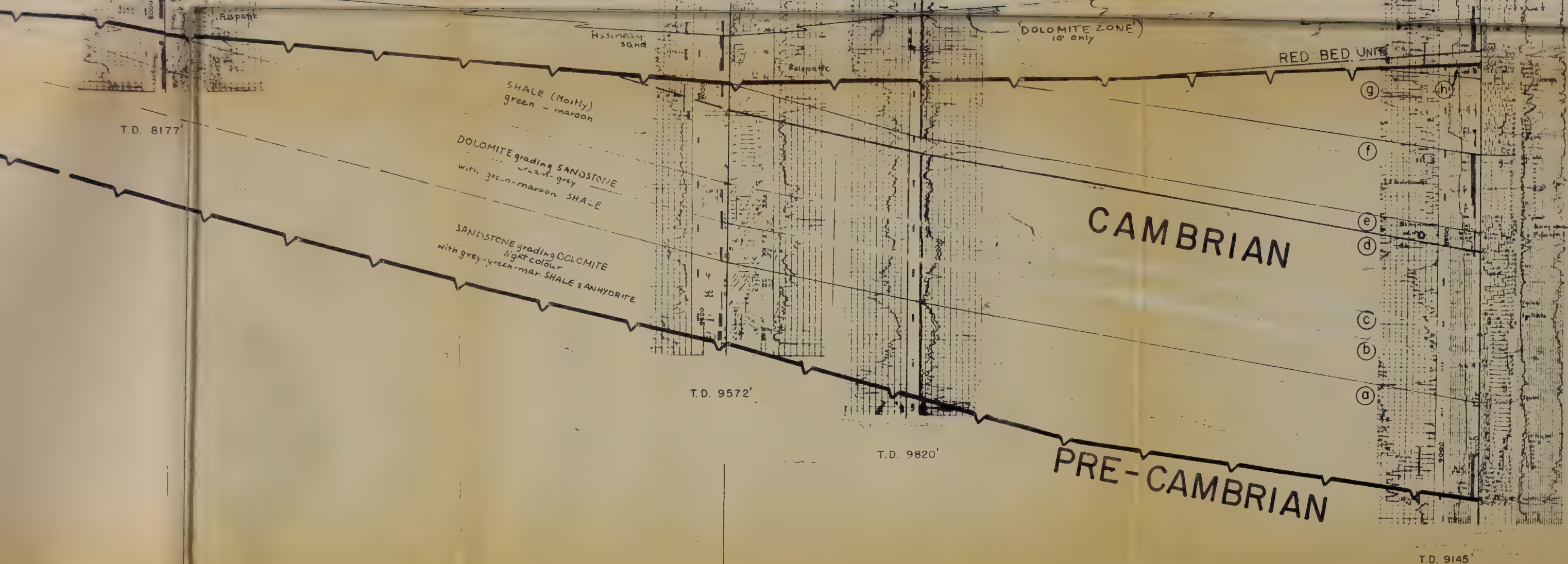
assuming — (a) TOP OF WOODBEND as a horizontal datum
— (b) TOP OF DEVONIAN (D1)

- COLOR GRAIN SEAVE POINT
 1 Limestone grey-tan, very fine x, argill. beds grading to limy shale
 2 Limestone light grey-tan, Kpx-fine x, uniform dense, may contain scattered fragments - dense
 3 Limestone buff-brown, fine-coarse x & sub x & sub frag. locally frag (pelletoid) porosity poor-fair
 4 Limestone white, buff & very light grey, M-Cx, uneven & coarse frags sub frags stromatopora common, porosity fair-excellent
 5 DOLOMITE tan-brown, Fx-Mx, tight
 6 DOLOMITE tan, grey, light brown, F-C, x-rx, locally sub frag porosity poor-good
 7 DOLOMITE white, cream & light grey, F-C, rx, porosity fair-excellent
 8 PETROLIFEROUS Limestone DOLOMITE dark brown, F-Cx, locally frag. amphipora common porosity tight-poor
 BRA Brachiopods & associated fauna
 A Amphipora
 S Stomatopora & associated fauna

T.D. 8177'

DOLOMITE
 with grey
 SAPPHIRE
 with grey





M M SUSKA
CALGARY-EDMONTON

CROSS-SECTION B

1
WINTER
BROWVALE I.
13-19-81-25-W5
K.B. 1970'

2
COLORADO, OKALTA
NORMANDVILLE 15-25
15-25-80-23 W.5
K.B. 1894'

4
SHELL
KIMIWAN I.
2-26-80-20W5
K.B. 2005'

5
SHELL IMP.
SPRINGBURN I.
14-34-80-17-W.5
K.B. 2476'

6
SHELL
RENO 16-25
16-25-80-17 W5
K.B. 2391'

7
UNION EVANS
NORTH HEART RIVER 5-23
5-23-80-16 W5
K.B. 2392'



7

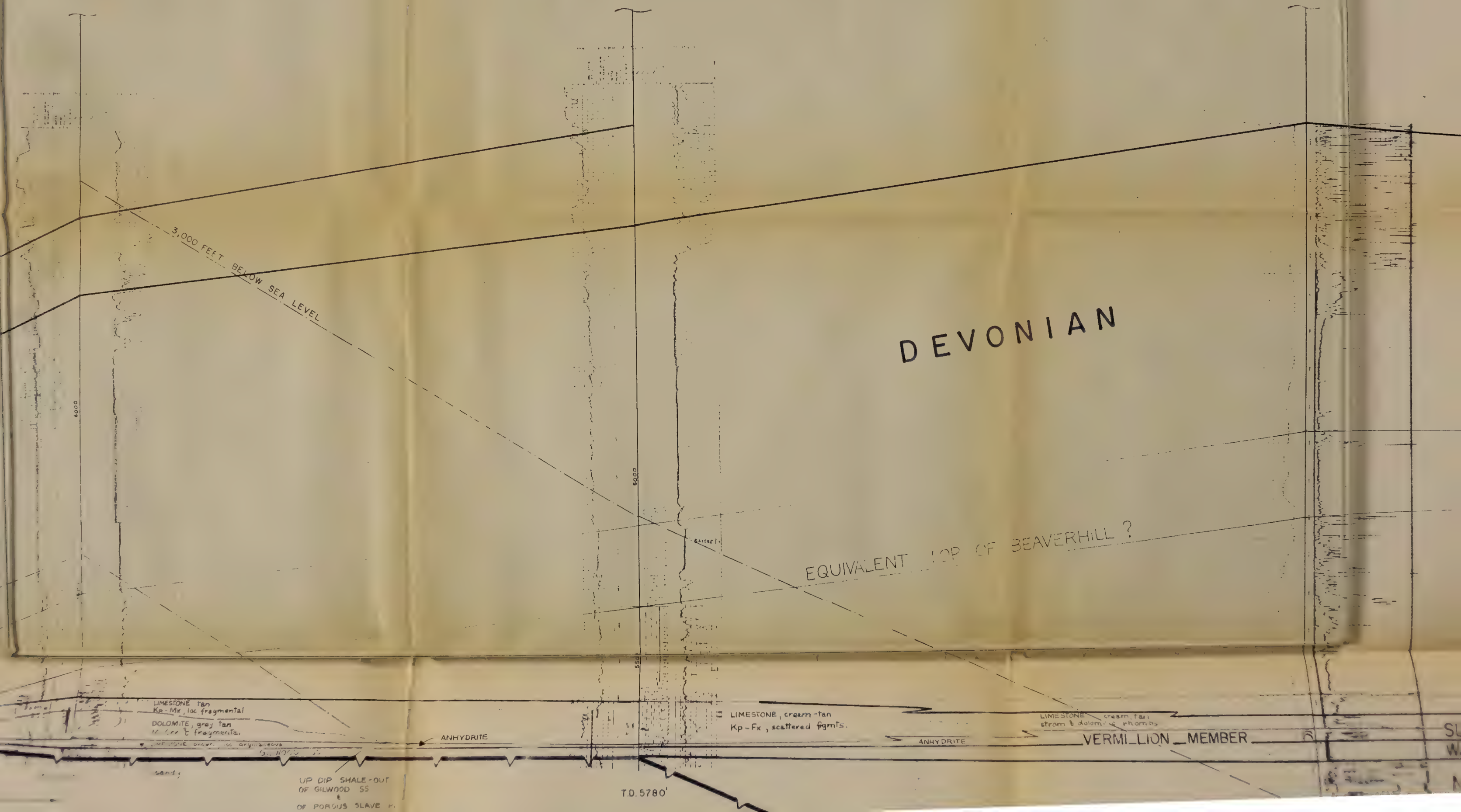
UNION EVANS
NORTH HEART RIVER 5-23
5-23-80-16 W5
K.B. 2392'

8

CAL. STANDARD
UTIKUMA RIVER 16-27
16-27-80-11 W5
K.B. 2152'

9

SINCLAIR ATLANTIC
UTI JMA NO. 16-16
16-16-81-5 W. 5
K.B. 2096'



9

SINCLAIR ATLANTIC

UTI JMA NO. 16-16

16-16-81-5-W.5

K.B. 2093'

10

IMP. FUTURITY

GODIN LK. 10-16

10-6-82-1-W.5

K.B. 1908'

WOODBEND

UNIT

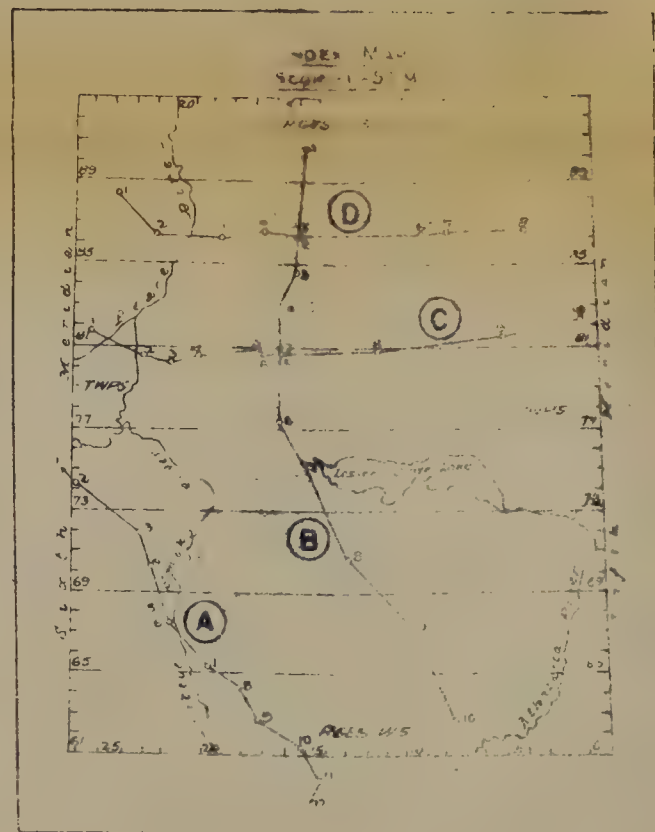
BEAVERHILL

ON MEMBER

SLAVE POINT FM.
WATT MOUNT. FM.

LIMESTONE, tan
Kp sub-fgmrl

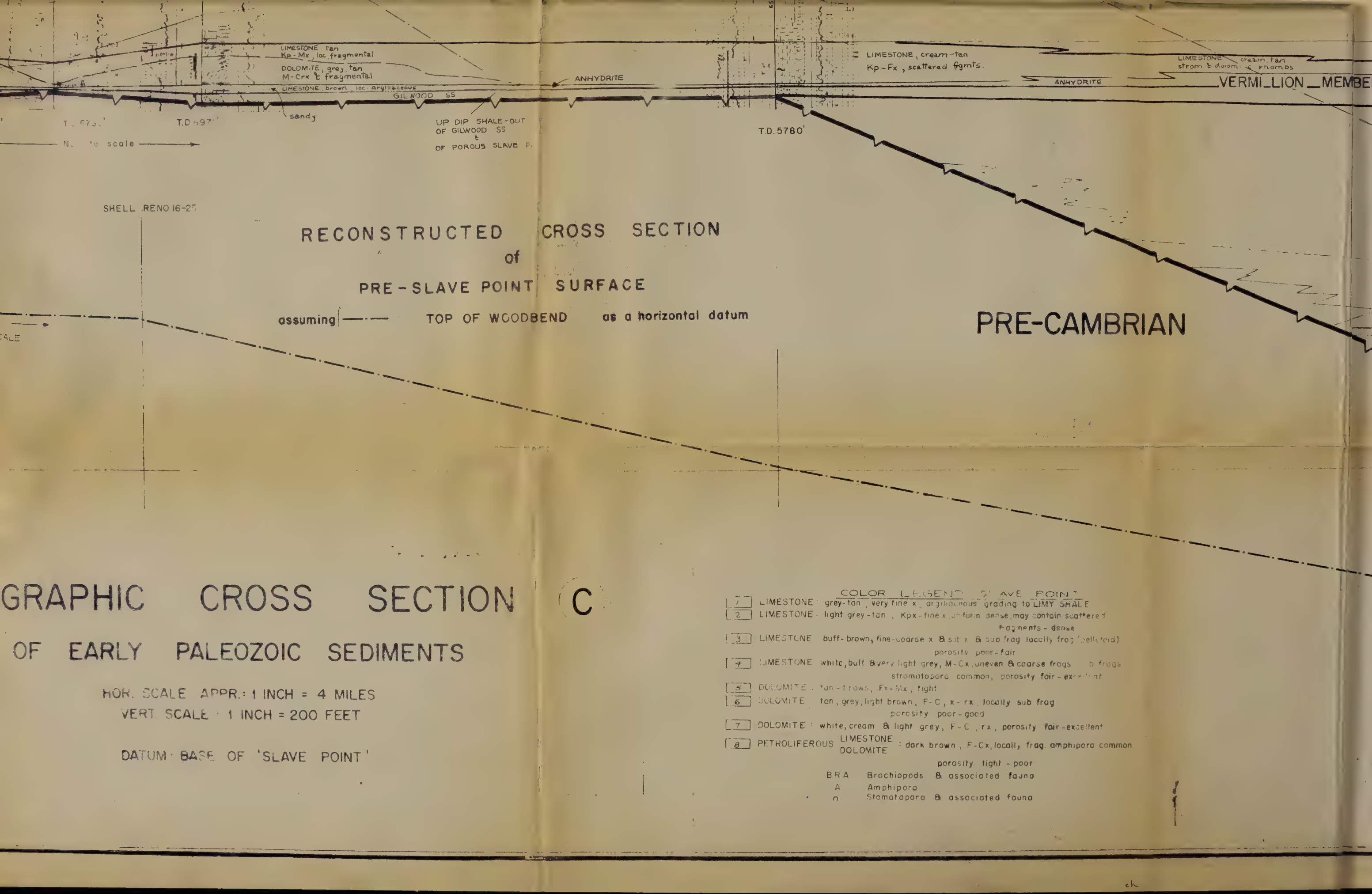
CRI



HORIZONTAL DATUM

STRATIGRAPHIC OF EARLY

HOR. SC.
VERT.
DATUM



ONE cream tan
& dolomitic rhombs

VERMILION MEMBER

SLAVE POINT FM.
WATT MOUNT. FM.

LIMESTONE tan
Kp sub-fossil

CRI

MUSKEG FM. EQU. CLASTIC &
EVAPORITIC
UNIT
upper zone

ELK POINT GR.

KEG RIVER EQU

SHALE ZONE

DOLOMITE ZONE

GRANITE

WASH

RED BED UNIT

TD 5800'

TD 5009'

M.M. SUSKA

CALGARY-EDMONTON

1

GREAT PLAINS ET AL
DIXONVILLE N91.
16-12-88-24-W.5
K.B. 2167'

2

PACIFIC
ST. GERMAINE I.
5-21-85-22 W.5
K.B. 2054'

3

SHELL
THREE CREEKS I.
5-12-86-19 W.5
K.B. 1963'

4

FOREST B.A.
CADOTTE
3-24-86-17-W.5
K.B. 2050'

5

CANADIAN SEABOARD
CADOTTE 10-16
10-16-86-15-W.5
K.B. 1959'



5

SEABOARD
DOTTE 10-16
-16-86-15-W.5
K.B. 1959'

6

IMPERIAL
LOON LAKE 8-22
8-22-86-9-W.5
K.B. 1820'

7

B. A.
LOON LAKE
10-20-86-8 W.5
K.B. 1929'

8

SHELL
MARIA LAKE. I.
2-28-86-4-W.5
K.B. 2266'

DEVONIAN

WOODBEND

UNIT

BEAVERHILL

2,500 FEET BELOW SEA LEVEL

EQUIVALENT TOP OF BEAVERHILL ?

?

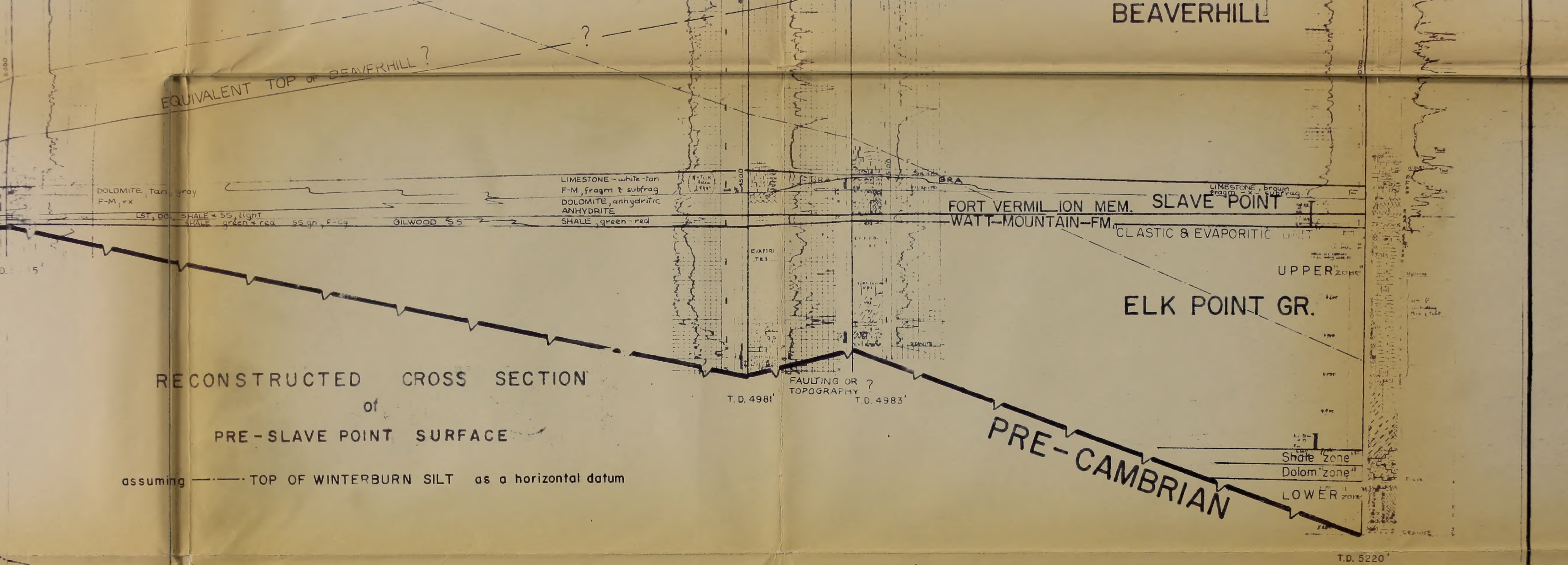
3000

2000

4000

BEAVERHILL

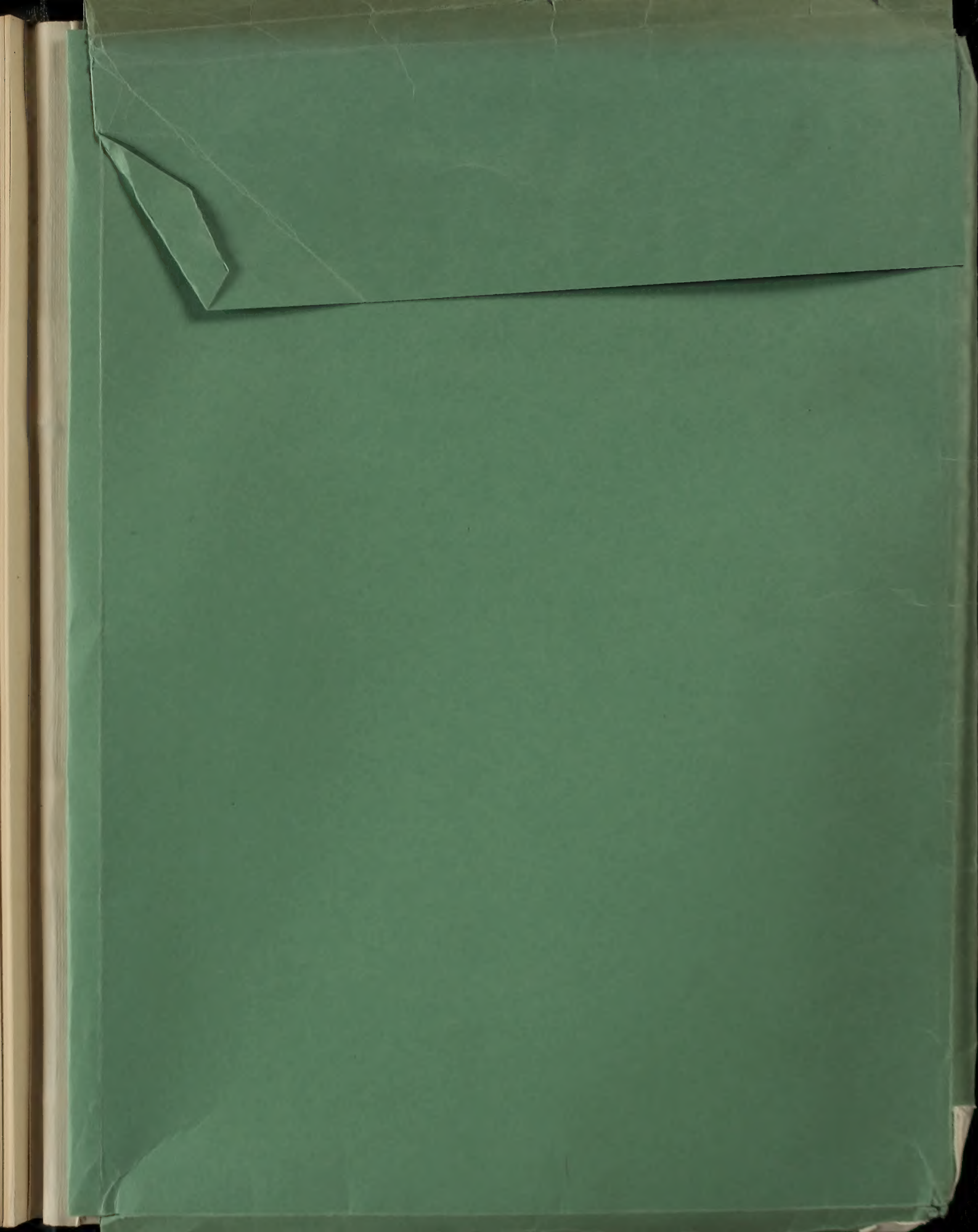
EQUIVALENT TOP of BEAVERHILL ?



D

- COLOR LEGEND SLAVE POINT
- 1 LIMESTONE: grey-tan, very fine x, argillaceous grading to LIMY SHALE
 - 2 LIMESTONE: light grey-tan, Kpx-fine x, uniform dense, may contain scattered fragments - dense
 - 3 LIMESTONE: buff-brown, fine-coarse x & sub x & sub frag, locally frag (pelletoid) porosity poor-fair
 - 4 LIMESTONE: white, buff & very light grey, M-Cx, uneven & coarse frags sub frags. stromatopora common, porosity fair-excellent
 - 5 DOLOMITE: tan-brown, Fx-Mx, tight
 - 6 DOLOMITE: tan, grey, light brown, F-C, x-rx, locally sub frag. porosity poor-good
 - 7 DOLOMITE: white, cream & light grey F-C, rx, porosity fair-excellent
 - 8 PETROLIFEROUS LIMESTONE DOLOMITE: dark brown, F-Cx, locally frag amphipora common porosity tight - poor
- BRA Brachiopods & associated fauna
- A Amphipora
- n Stromatopora & associated fauna

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